PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

VOL. 13, NO. 9 ▽ NOVEMBER, 1932

A BRICK PAVEMENT 19 YEARS AFTER ITS CONSTRUCTION

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - - - - - - - See page 2 of cover for prices

PUBLIC ROADS ▸ ▸ ▸ *A Journal of Highway Research*

Issued by the

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

G. P. St. CLAIR, *Editor*

Volume 13, No. 9 November, 1932

The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to the described conditions.

In This Issue

THE BUREAU OF PUBLIC ROADS - - - - Willard Building, Washington, D. C.
REGIONAL HEADQUARTERS - - - - - - - - - Mark Sheldon Building, San Francisco, Calif.

DISTRICT OFFICES

DISTRICT No. 1. Oregon, Washington, and Montana.
Post Office Building, Portland, Oreg.

DISTRICT No. 2. California, Arizona, Nevada, and Hawaii.
Mark Sheldon Building, 461 Market St., San Francisco, Calif.

DISTRICT No. 3. Colorado, New Mexico, and Wyoming.
237 Custom House, Nineteenth and Stout Sts., Denver, Colo.

DISTRICT No. 4. Minnesota, North Dakota, South Dakota, and Wisconsin.
410 Hamm Building, St. Paul, Minn.

DISTRICT No. 5. Iowa, Kansas, Missouri, and Nebraska.
Saunders-Kennedy Building, Omaha, Nebr.

DISTRICT No. 6. Arkansas, Louisiana, Oklahoma, and Texas.
1912 Fort Worth National Bank Building, Fort Worth, Tex.

DISTRICT No. 7. Illinois, Indiana, Kentucky, and Michigan.
South Chicago Post Office Building, Chicago, Ill.

DISTRICT No. 8. Alabama, Georgia, Florida, Mississippi, South Carolina, and Tennessee.
Shepherd Building, P. O. Box J, Montgomery, Ala.

DISTRICT No. 9. Connecticut, Maine, Massachusetts. New Hampshire, New Jersey, New York, Rhode Island, and Vermont.
Federal Building, Troy, N. Y.

DISTRICT No. 10. Delaware, Maryland, North Carolina, Ohio, Pennsylvania, Virginia, and West Virginia.
Willard Building, Washington, D. C.

DISTRICT No. 11. Alaska.
Room 419, Federal and Territorial Building, Juneau, Alaska.

DISTRICT No. 12 Idaho and Utah.
Federal Building, Ogden, Utah.

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in planning or constructing public highways, instructors in highway engineering, and periodicals upon an exchange basis. Others desiring to obtain PUBLIC ROADS can do so by sending $1 per year (foreign subscription $1.50), or 10 cents per single copy, to the Superintendent of Documents, United States Government Printing Office, Washington, D. C.

ROAD IMPACT PRODUCED BY A HEAVY MOTOR BUS

Reported By **JAMES A. BUCHANAN**, Associate Engineer of Tests, United States Bureau of Public Roads

DETERMINATION of the magnitude of the impact forces exerted on the pavement by the wheels of motor trucks and busses has been the object of an extended series of investigations by the Bureau of Public Roads, in cooperation with the Rubber Manufacturers' Association and the Society of Automotive Engineers. In the course of these investigations the major factors which affect the magnitude of such impact reactions have been separately and collectively studied both in the field and in the laboratory. In order to round out this research a final series of tests has been made with a bus chassis capable of carrying heavy loads at high speeds, to anticipate, in some measure at least, the trend in operating conditions for several years to come.

CONCLUSIONS DERIVED FROM BUS IMPACT TESTS

1. With balloon tires as used in these tests, reactions of about three times the static wheel load may be encountered in isolated cases, generally where pavement failure has already occurred and repairs are necessary.
2. A few reactions amounting to twice the static wheel load may be expected for each mile of rough surface.
3. The frequent reactions for rough surfaces amount to about 1.5 times the static wheel load.
4. Even the smoothest roads produce frequent reactions of from 1.1 to 1.2 times the static wheel load.
5. Concerning the maximum reactions produced at a large number of individual roughness conditions, the general tendency is for this maximum to increase in approximate proportion to speed up to about 40 miles per hour, and at speeds greater than that comparatively slight increases in reaction are noted. However, occasional roughness conditions may occur where the maximum reaction developed at 20 or 30 miles per hour is as great as the maximum produced by the majority of the roughnesses at only the higher speeds.

PURPOSE OF THE TESTS

This series of tests was planned with three objects in mind. First, data were desired concerning the magnitudes of the impact reactions produced at high operating speeds and the relative magnitudes of the shock and drop types of reaction throughout the full range in speed represented by modern operating conditions. Second, more complete data were desired concerning the magnitude of the reactions developed by a considerable number of severe but typical roughness conditions occurring on the surfaces of highways in actual use. Third, data were desired concerning the relation between the magnitude of reaction and the frequency of occurrence for the full range of surface roughness of highways. The data obtained in these tests and the conclusions drawn therefrom are presented herewith.

HEAVY-DUTY BUS SELECTED

The vehicle selected for use in these tests was a 240-inch wheel-base, heavy-duty bus chassis. It was designed to have a gross weight of 24,000 pounds, and this was obtained in the tests by placing iron weights on a special platform body, as shown in Figure 1. The front-axle load was 8,000 pounds and was carried by 9.75–24 inch balloon tires throughout the tests. The rear-axle load of 16,000 pounds was carried on interchangeable 9.75–24 inch dual and 12.75–24 inch single balloon tire equipments. The respective tires were inflated to pressures recommended by the Tire and Rim Association for the capacity load carried.[1] The vehicle had an available speed range of 0 to 80 miles per hour. The average unsprung weight at the right rear wheel was 1,817 pounds.

STATIC TESTS

The tires were subjected to the usual tests under static load conditions. The curves of static load versus vertical deformation for the single and dual tire equipments used on the rear wheels are given in Figure 2. It has been the experience throughout all the tests that dual tires of a given type are somewhat less cushioning than single tires of the same type and of corresponding carrying capacity. The reason for this is found in the respective cross-sectional dimensions of the two types of mounting. A single tire has greater sectional depth than dual tires of the same type and carrying capacity. This greater depth permits greater vertical deformations which decrease the abruptness of velocity changes or accelerations imparted to the axle and correspondingly decrease the dynamic components of the impact reactions.

In Figure 3 data are given concerning the areas of contact between the tires and a plane reacting surface under static loads. The area of contact is taken as the entire area within the outline of the impression. The broken line in this figure represents the entire area under the influence of the dual tires. This gross area was obtained by multiplying the length of a given contact impression by the center to center spacing of the dual tire mounting and adding to this product the contact area for one of the tires in the dual mounting.

Data concerning the static tests of the tires are given in Table 1. The areas of contact are included because they have a bearing on the stresses developed within the pavement structure.

TABLE 1.—*Data from static tests of tires*

Tire size ________ inches	9.75–24	12.75–24
Mounting	Dual.	Single.
Plies	10	16
Rim size ________ inches	24 x 8	24 x 11
Dual spacing ________ do	12	________
Inflation pressure ________ lbs. per sq. in	63	90
Vertical deformation:		
8,000-pound wheel load ________ inches	1.23	1.49
16,000-pound wheel load ________ do	2.17	2.62
24,000-pound wheel load ________ do	3.08	3.72
Gross contact area[2]:		
8,000-pound wheel load ________ sq. ins	192	92
16,000-pound wheel load ________ do	282	162
24,000-pound wheel load ________ do	354	211
Average unit pressure based on gross contact area:		
8,000-pound wheel load ________ lbs. per sq. in	42	87
16,000-pound wheel load ________ do	57	99
24,000-pound wheel load ________ do	68	114

INSTRUMENTATION DESCRIBED

As in former tests, the method of determining the magnitudes of the impact forces was to measure the accelerations imparted to a rear wheel by means of contact-type accelerometers rigidly mounted on the

---

[1] The inflation pressures were determined with a calibrated Bourdon-tube pressure gage. Frequent observations of inflation pressures were made throughout the tests.

[2] Gross contact area for dual tires includes area between the tires. It is obtained by multiplying the contact length by the dual spacing and adding the area of contact of a single tire.

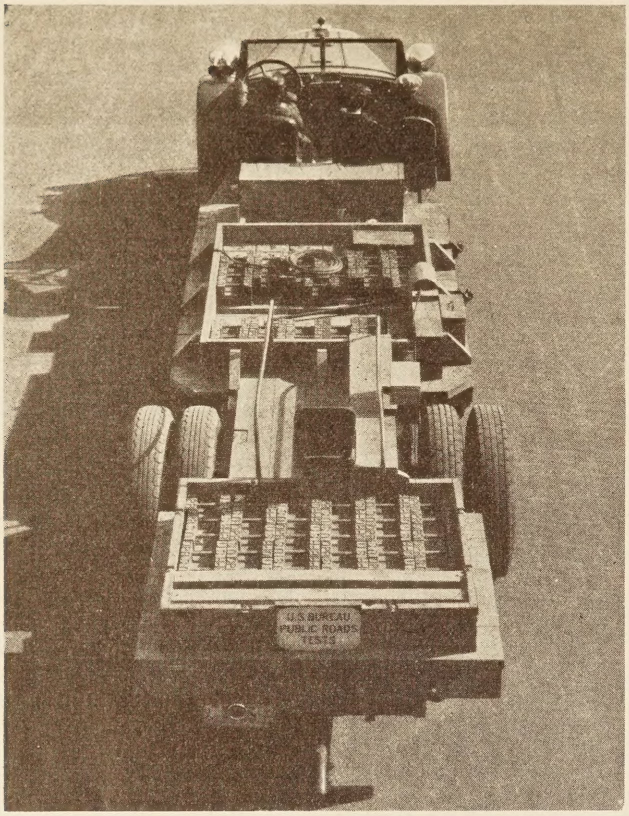


Figure 1.—The Bus Chassis as Used in the Tests, Showing the Arrangement of 100-Pound Weights

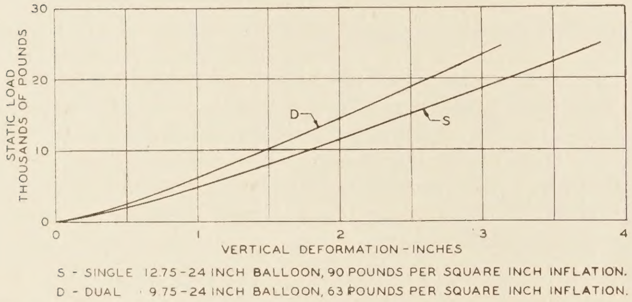


Figure 2.—Static Load-Deflection Curves of the Tires

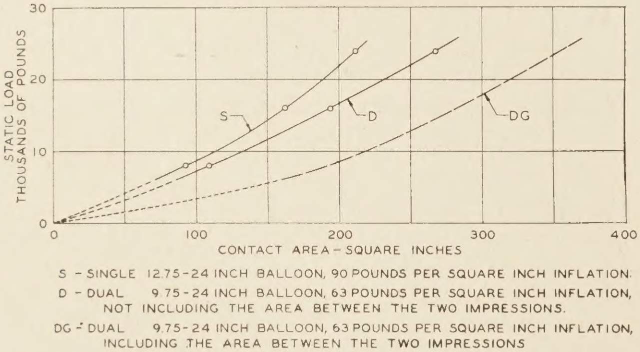


Figure 3.—Static Load-Contact Area Curves of the Tires

rear axles at the saddle which received the vehicle spring. The principle involved in the use of these contact accelerometers is briefly described as follows:

A pivoted weight or inertia element is restrained from oscillation, except through a minute arc, by two adjustable screws which also constitute electric contacts. A calibrated cantilever spring is attached to the pivoted weight. This spring is deflected known amounts by a micrometer adjustment at its outer end. The pressure imposed on the spring causes the inertia element to exert a known force against one of the contact stop screws. The accelerometer unit, being rigidly fastened to the vehicle axle, receives the accelerations imparted to the axle. When the product of the imparted acceleration and the mass of the inertia element is a force greater than the force due to the deflected cantilever spring, the inertia element will break away from one contact stop screw, travel not more than two-thousandths of an inch and make contact with the other contact stop screw. Whether or not this movement takes place, i. e., whether or not the imparted acceleration exceeds the acceleration corresponding to a given deflection at the micrometer adjustment of the cantilever spring, is determined by an autographic record or by means of a telephone circuit.

The 10-element, autographic, contact-type accelerometer was fully described in an earlier report on impact tests which appeared in the April, 1931, issue of Public Roads. This instrument, which is shown in Figure 4, was used in the tests involving artificial obstructions and natural roughness conditions. Because of the great length of records which would have been involved, the autographic instrument was not used in the tests conducted over the half-mile lengths of typical road surfaces. For these latter tests a single-element contact accelerometer recording through telephones was used.

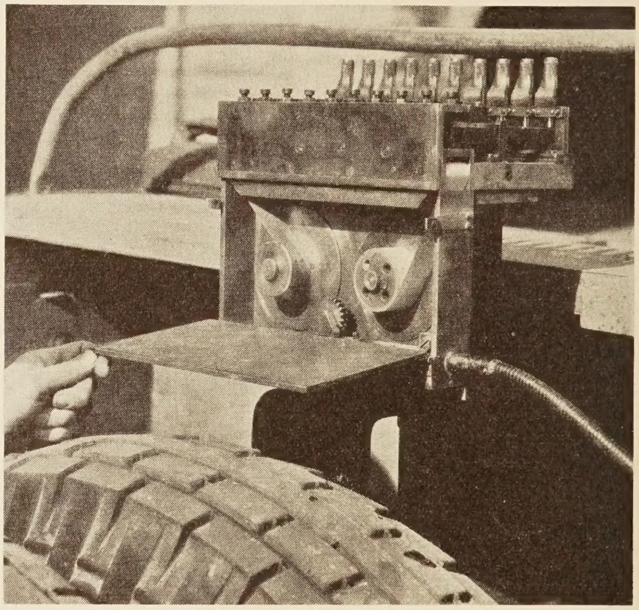


Figure 4.—The 10-Element Autographic Contact Accelerometer Mounted at the Rear Wheel. The Open Cover Shows the Method of Drawing Special Paraffin-Coated Paper Beneath the Styli Attached to the Accelerometer Elements. The Flexible Shaft at the Right Contains a Cable Driven by an Electric Motor

The single-element, telephone-recording instrument, which is shown as used in the tests in Figure 5, was described in the July, 1930, issue of Public Roads, in an article dealing with the instrumentation involved in motor vehicle impact tests. There was the following modification in the method of observing the action of the single-element accelerometer. The telephone circuit was arranged with three head sets in parallel which were used by three observers simultaneously. In this

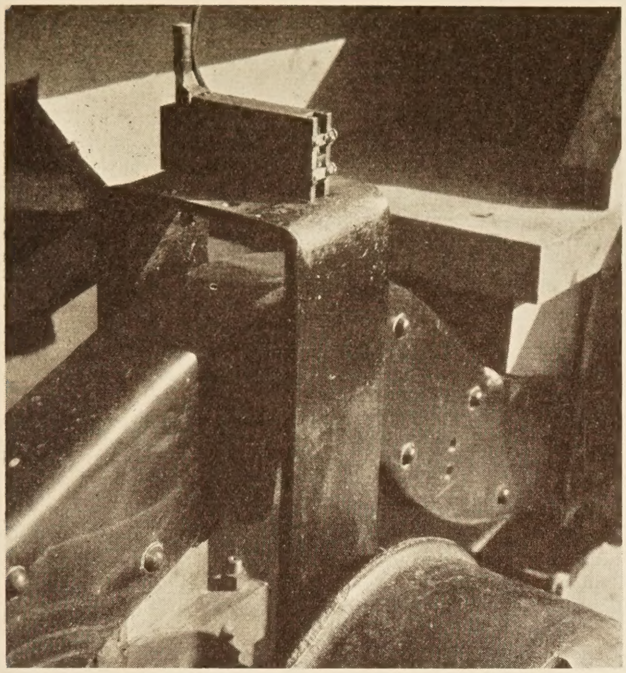


FIGURE 5.—THE SINGLE-ELEMENT CONTACT ACCELEROMETER MOUNTED ON THE YOKE WHICH IS BOLTED TO THE REAR AXLE AT THE SPRING PAD

way a check was obtained on the counts of the number of times an acceleration of a given magnitude was imparted to the axle during the course of a test run. By making a number of runs for which the acceleration setting was successively increased until no response was recorded, the desired data on acceleration versus frequency of occurrence were readily obtained for each road test condition.

The impact force was obtained in the usual manner by multiplying the mass of the unsprung weight at the rear wheel by the acceleration as determined in each test and adding to this product (which is the dynamic increment) the static weight on the wheel.[3] The flexing of the vehicle spring above or below its static load position may cause minor variations of the actual total force from the force as computed by this method. It has been pointed out in the earlier publications, however, and justified by experimental evidence, that the complication of the test procedure involved in securing data to make a correction for this variation is not warranted by the nature of the tests. The average pressure exerted by the spring is approximately that of the static load position. The contact accelerometer is not particularly adapted to the task of obtaining a simultaneous record of the flexing of the vehicle spring, and, in the interest of simplification of instrumentation and test procedure such corrections have not been made.

What the nature of the corrections would be in the case of the artifical obstructions has been clearly indicated by the truck impact tests described in PUBLIC ROADS, volume 7, No. 4, June, 1926. In these tests the sprung component of the impact force was measured. In the case of shock it appears, from both theory and observation, that the maximum impact takes place at a point when the axle is only slightly lifted above its normal rolling position, and for this reason the increase in spring pressure under shock conditions is negligible.

In the case of drop after striking an artificial obstruction it was found that in practically all cases the spring pressure was reduced below its value under static conditions. The explanation of this phenomenon appears to be about as follows. The body, as a result of the force applied by the shock, starts upward in a swing which is of relatively long duration compared to the more violent oscillations of the axle. At the instant of maximum drop impact the body has very likely not returned to its static level. At the same time the axle has been depressed below its static position by an amount equal to the increased deflection of the tire under the drop impact. The result is a reduction of the spring pressure. With very light loads it has been found that this parting of the wheel and body is at times so great as to put the spring in tension. With heavy loads, such as those used in the bus tests, this does not occur, but a considerable reduction of the spring pressure may take place.

Had the spring deflections been measured in the tests with artificial obstructions the impact forces shown in Figures 6 and 7 would have been less than those plotted. In the case of natural obstructions it is impossible to determine in what phase of their relative motion the sprung and unsprung masses may be at the instant of impact. The spring pressure under static load has therefore been taken as representing a fair average for all road conditions.

TESTS INVOLVING ARTIFICIAL OBSTRUCTIONS

The data obtained in that portion of the tests which involved the artificial obstructions are given in Figures 6 and 7. In addition to yielding information concerning the relative magnitudes of shock and drop reactions at speeds up to 75 miles per hour these tests serve as a tie-in to the earlier impact investigations where artificial obstructions were used on an otherwise smooth, level road surface.

Three steel obstructions were used. The 1½ by 30 inch inclined plane and the 1½ by 12 inch rectangular obstruction were the same as those used in previous tests, while the 1 by 12 inch rectangular obstruction was introduced in these tests. The method of securing them in place was by bolting them to nuts set in the concrete pavement, and only one obstruction was placed on the road at any time. Data for both shock and drop conditions were taken with all three obstructions.

The tests involving the use of artificial obstructions were made on a completed section of the Mount Vernon Memorial Highway before it was opened to general traffic. It was fortunate that a portion of this smooth, wide highway could be made available for this work and provisions made for controlling all other traffic while the tests were in progress. The vehicle used had a gross weight of 12 tons and, although speeds of about 80 miles per hour, or 120 feet per second, were attained, the tests were conducted without danger to life or property.

In Figure 6 the data are given for the tests with the dual 9.75–24 inch balloon tires over the three artificial obstructions and Figure 7 gives the corresponding data for the single 12.75–24 inch balloon. The inflation pressures were maintained at 63 and 90 pounds per square inch, respectively, in these and all subsequent tests.

---

[3] This is expressed by the equation

$$F=mA+L,$$

in which

F=total vertical reaction per rear wheel.
m=mass of unsprung weight per rear wheel.
A=acceleration imparted to unsprung mass.
L=static load on pavement, per rear wheel.

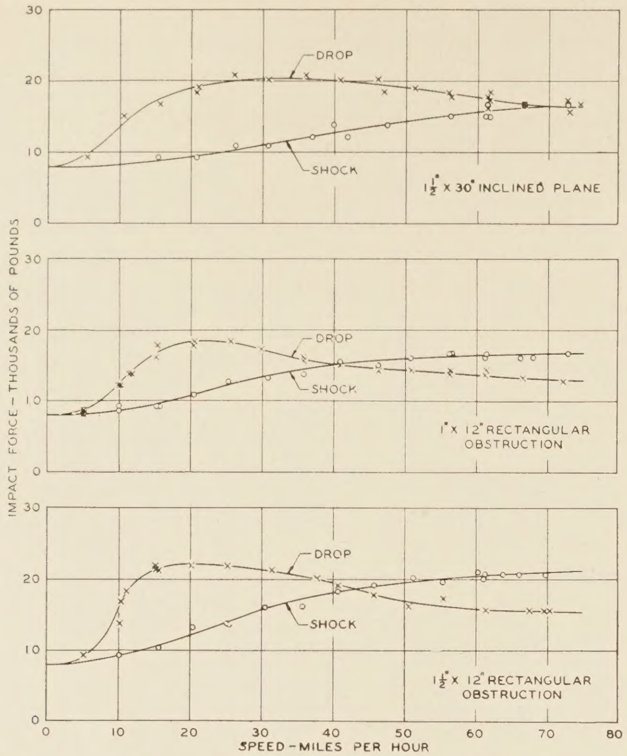


Figure 6.—Impact Tests with Artificial Obstructions and Dual 9.75–24 Inch Balloon Tires at 63 Pounds per Square Inch Inflation

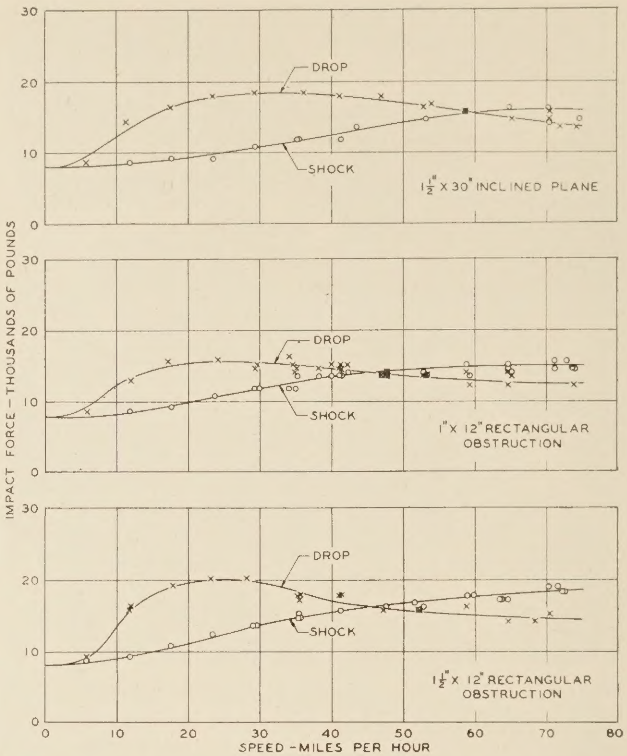


Figure 7.—Impact Tests with Artificial Obstructions and Single 12.75–24 Inch Balloon Tires at 90 Pounds Per Square Inch Inflation

These data show the distinct tendency for the curves representing shock reactions to flatten out at the higher speeds. It is significant that the shock reactions do not, even at a speed of 75 miles per hour, reach magnitudes as great as those reached by the corresponding drop reactions at speeds between 20 and 40 miles per hour. This relation leads to the important conclusion that, in so far as artificial obstructions such as these are concerned, the reactions of a motor vehicle wheel equipped with balloon tires tend to reach a maximum value at a speed between 20 and 40 miles per hour.

In connection with this discussion of the tendency for shock reactions to approach a maximum value as the speed is increased, it is noted that the maximum shock is reached with the 1-inch rectangular obstruction at a lower speed than is the case with the 1½-inch obstruction. This is in accord with the discussion of the theory underlying this phenomenon as brought out in the April, 1931, issue of Public Roads. When an obstruction is encountered by a tire in its travel over a road surface there is a tendency for the tire to envelop the obstruction by a local deformation of the cushioning material. As the speed increases the time during which a given obstruction is passing under the tire is decreased. If the obstruction is not too large and the tire has sufficient cushioning qualities, then at some speed the tire will substantially absorb the roughness condition without appreciably elevating the vehicle axle. The curve representing the shock reaction will increase up to that critical speed, and any increase in speed beyond the critical speed will show little or no increase in shock reaction for the given obstruction and tire equipment conditions. On the other hand, when the axle is raised as the result of a shock reaction, there is a corresponding and ensuing drop reaction. If the elevation of the axle due to shock gradually decreases with increases of speed, then the corresponding drop reaction will proportionately decrease.

In theory this elevation of the axle will approach zero as a limit when the speed is indefinitely increased. If this theoretical limit were ever reached the corresponding drop reaction would necessarily be zero. However, within the practical working limits defined by these tests, it appears that when the shock reaction approaches a maximum for a given obstruction and tire the elevation of the axle due to shock approaches a constant value as evidenced by the approach of the corresponding drop reaction to a constant value of relatively low magnitude.

Figures 6 and 7 bring out two other interesting facts. One is that an inclined plane of the dimensions of that used in the tests can produce appreciable shock reactions at high speeds. The other supports a conclusion drawn in earlier reports that the impact reactions developed by dual tires are slightly greater than those developed by single tires of the same type and having the same capacity as the duals.

TESTS INVOLVING NATURAL OBSTRUCTIONS

The natural obstructions used in the second phase of the program represent the worst which could be found at places where reasonable speeds could be attained in an area of more than 1,100 square miles, involving about 400 linear miles of primary and secondary roads in the vicinity of Washington, D. C. Tests were conducted at 28 locations throughout the full range of safe speeds possible at each. The load condition was the same as in the tests involving artificial obstructions. The dual 9.75—24 inch tires were used in tests at all locations, and in one case (fig. 22) additional tests were made with the single 12.75–24 inch tire.

As some of the tests over the natural obstructions were made at speeds considerably in excess of the legal limit, a special police detail of trained officers was made available to direct and control traffic in order that the

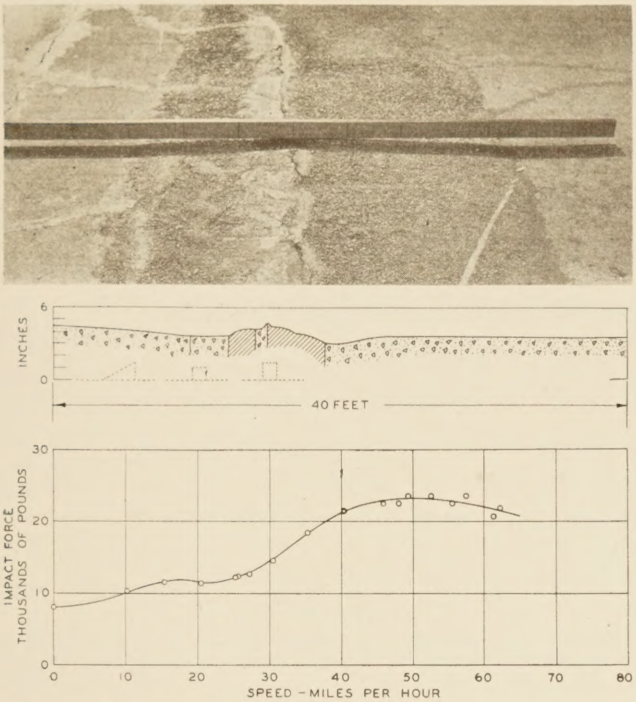


Figure 8.—Impact Reactions Produced on a Concrete Pavement at a Heaved Joint

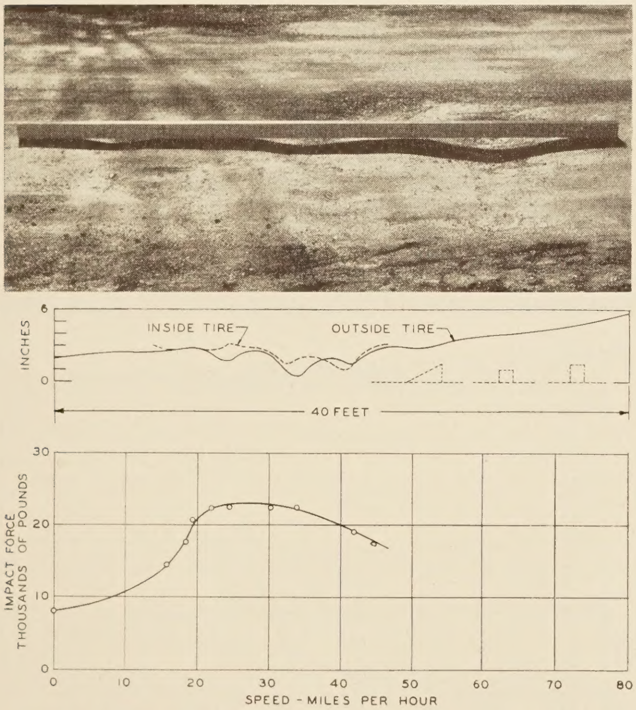


Figure 9.—Impact Reactions Produced on a Water-bound Macadam Road by Corrugated Surface

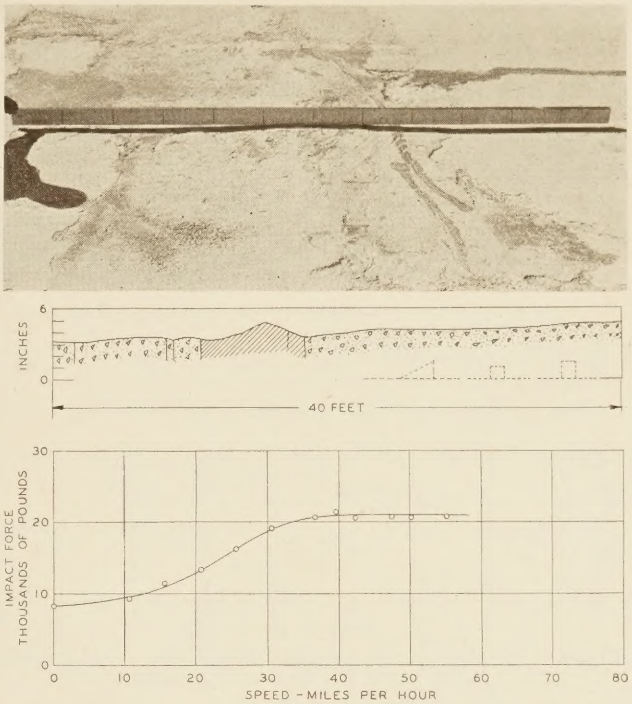


Figure 10.—Impact Reactions Produced at a Rough Bituminous Patch on a Concrete Pavement

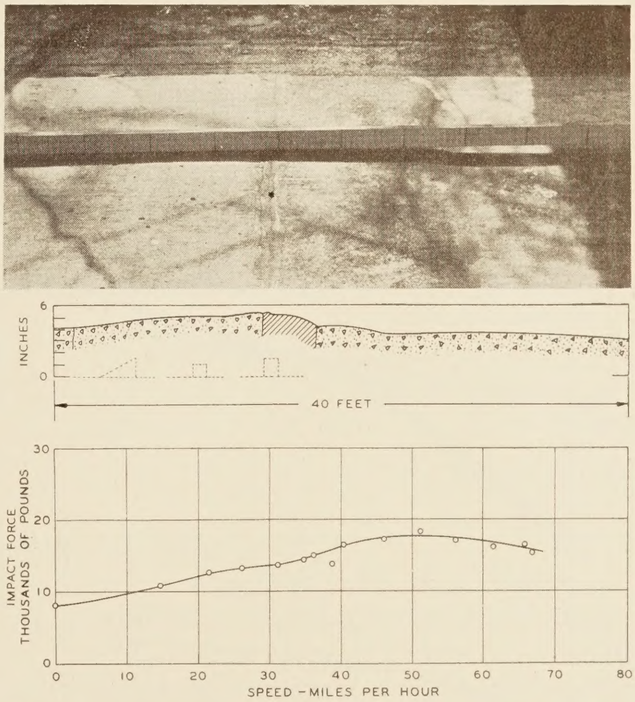


Figure 11.—Impact Reactions Produced on a Concrete Road by a Heave at a Joint Partly Repaired with Bituminous Material

high speeds might be safely attained. This courtesy was extended through the cooperation of the State roads commission and the commissioner of motor vehicles of the State of Maryland.

The data obtained in tests at 16 of the natural obstructions have been selected as representative and are presented in Figures 8 to 23, inclusive. These figures show the relation between the magnitude of the maximum impact reaction (whether shock or drop) and the vehicle speed as developed by the test bus at each of these very rough places in the highway surfaces.

The character of the surface at each location is shown by both a photograph and a profile taken along the path traversed by the right rear wheel of the test vehicle, which passed from left to right along the road surface as shown. The photograph gives a general

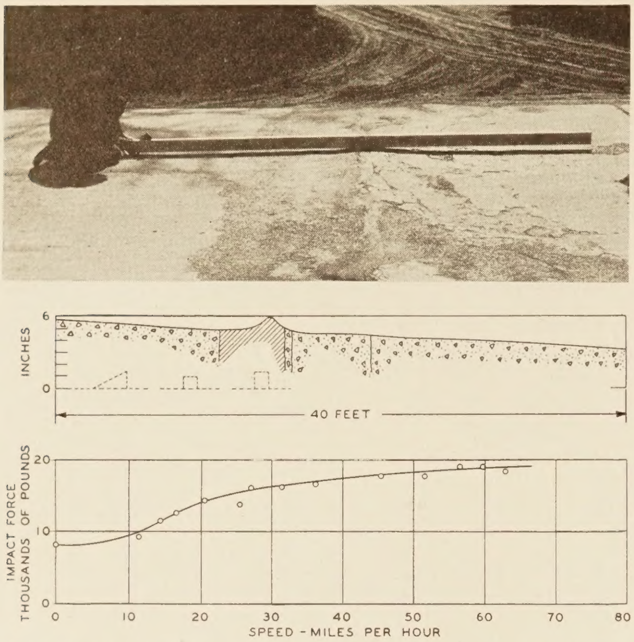


Figure 12.—Impact Reactions Produced at a Heaved Joint on a Concrete Pavement

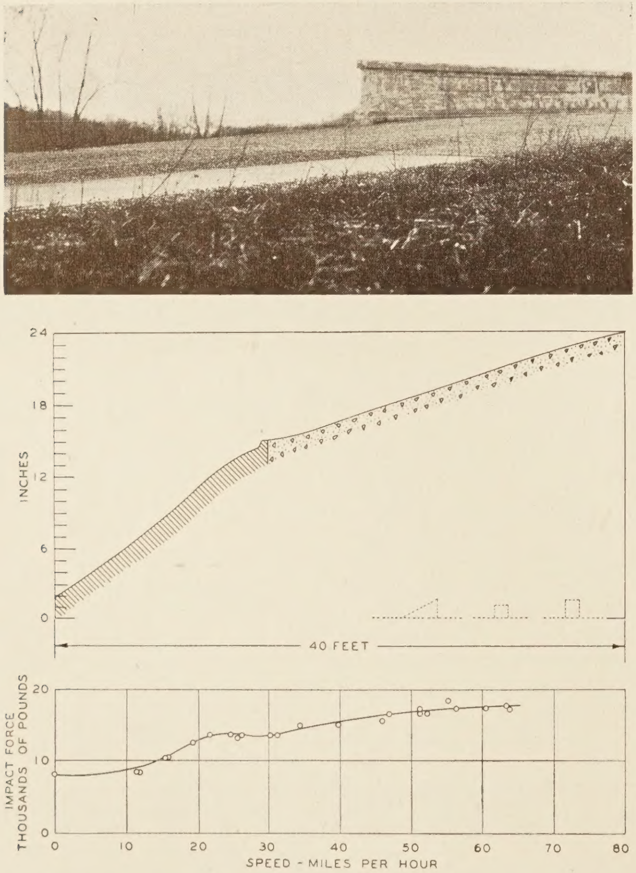


Figure 13.—Impact Reactions Produced on a Concrete Bridge by the Sharp Rise to the Bridge from a Road at a Lower Grade

picture of the rough spot. The straightedge, to be seen in most of the photographs, is 4 inches in height and 12 feet long, and is marked off in 1-foot intervals throughout its length. The shadow thrown on the pavement by this straightedge gives an excellent idea of the roughness of the road surface. The profiles, shown to a greatly distorted scale, are intended to give the details of the surface for engineering purposes rather than a "picture" of conditions as they existed. This fact should be kept in mind whenever an attempt is made to compare the size or shape of the natural rough-

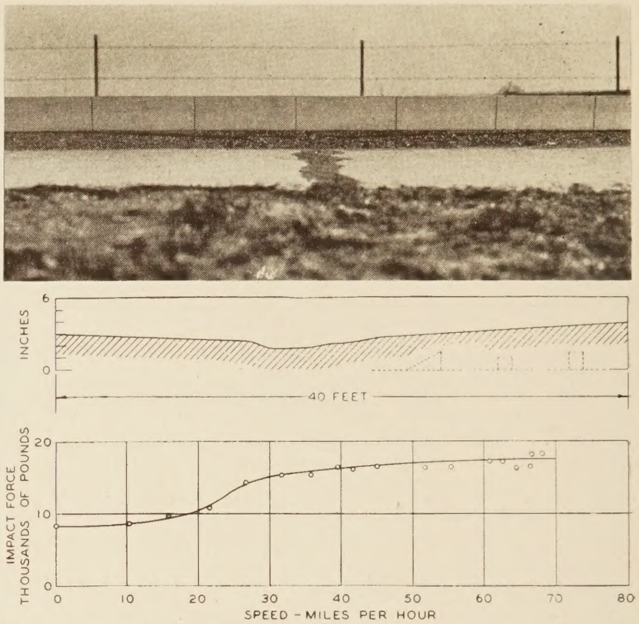


Figure 14.—Impact Reactions Produced on a Bituminous Pavement by Settlement of Back-fill Over a Culvert Pipe

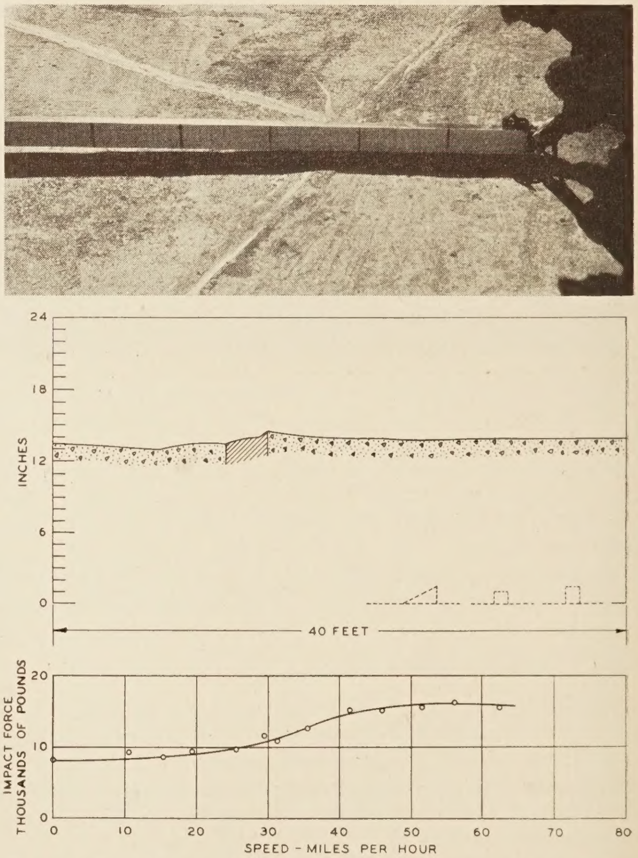


Figure 15.—Impact Reactions Produced on a New Concrete Bridge by Settlement of Fill Under Concrete Approach

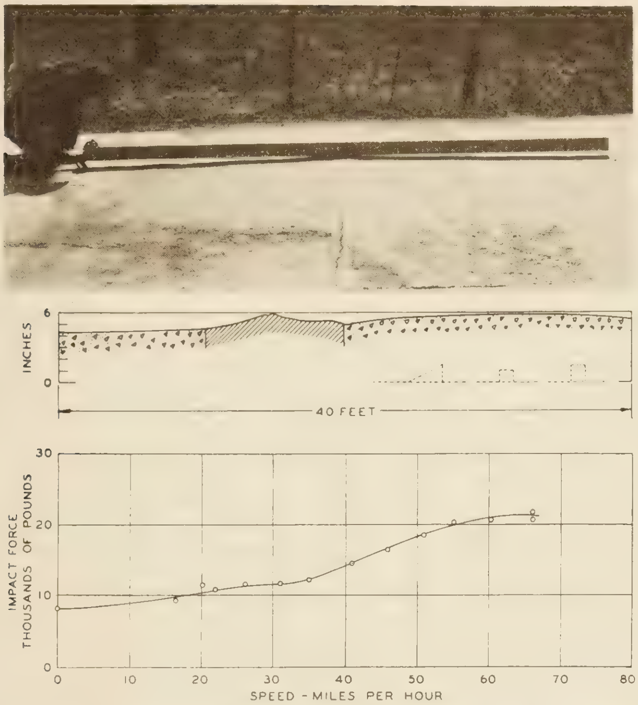


Figure 16.—Impact Reactions Produced on a Concrete Road. A Heaved Joint has been Repaired with Bituminous Mixture, but the Heaving has Apparently Continued

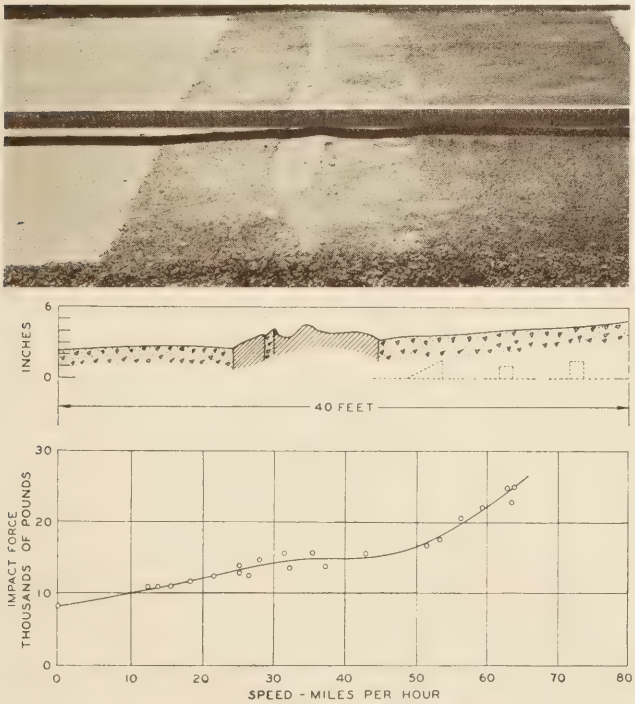


Figure 17.—Impact Reactions Produced on a Concrete Pavement at a Bad Joint which has been Patched with Bituminous Mixture

nesses as shown on the profiles with that of the artificial obstructions used in the first part of the program of tests. These three artificial obstructions, the 1½ by 30 inch inclined plane, the 1½ by 12 inch rectangular obstruction, and the 1 by 12 inch rectangular obstruction, are shown on each drawing to the same distorted scale as the profiles in order that their shapes may be compared with those of the natural obstructions.

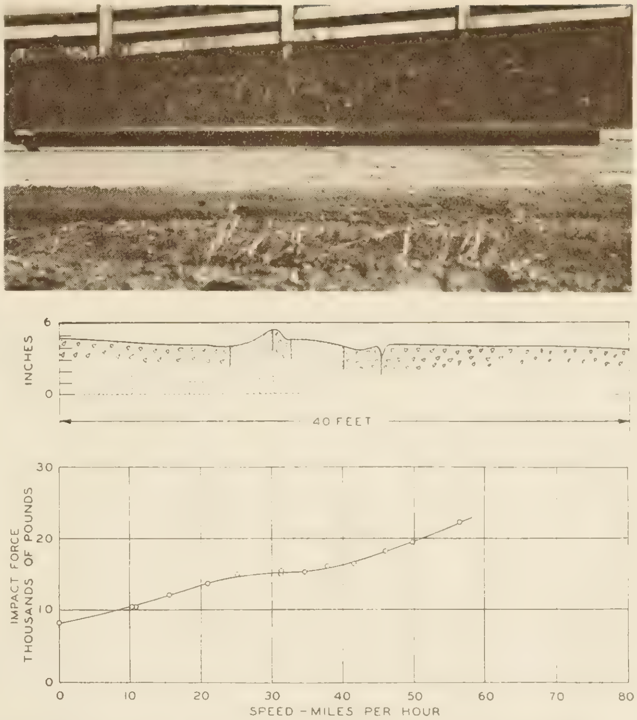


Figure 18.—Impact Reactions Produced at a Bituminous Patch in a Concrete Pavement

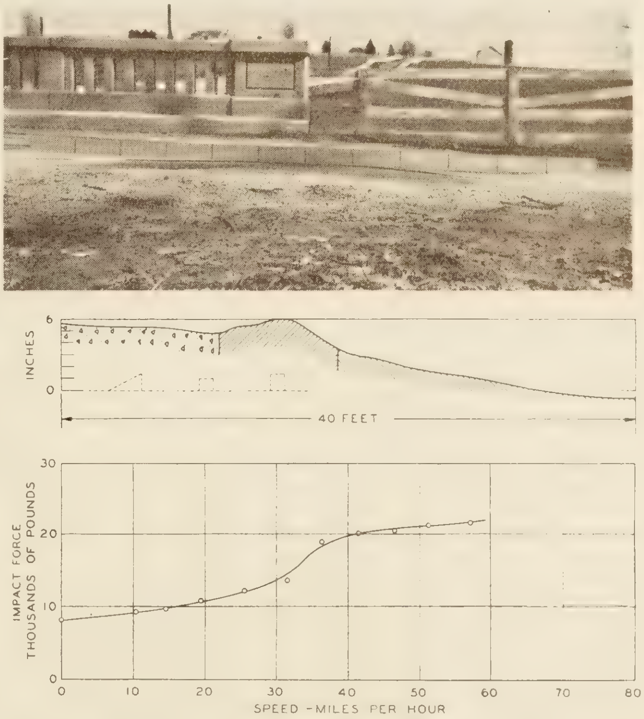


Figure 19.—Impact Reactions Produced on a Macadam Road by the Unevenness of the Grade at a Bridge Connection

The impact force produced at a given natural obstruction may not be directly comparable to that developed in the tests with the artificial obstructions, even though the two appear to be of approximately corresponding dimensions. The shape of the artificial obstructions is conventional, and in the tests they were placed on an extremely smooth, level stretch of new concrete pavement which had a very flat crown. Dur-

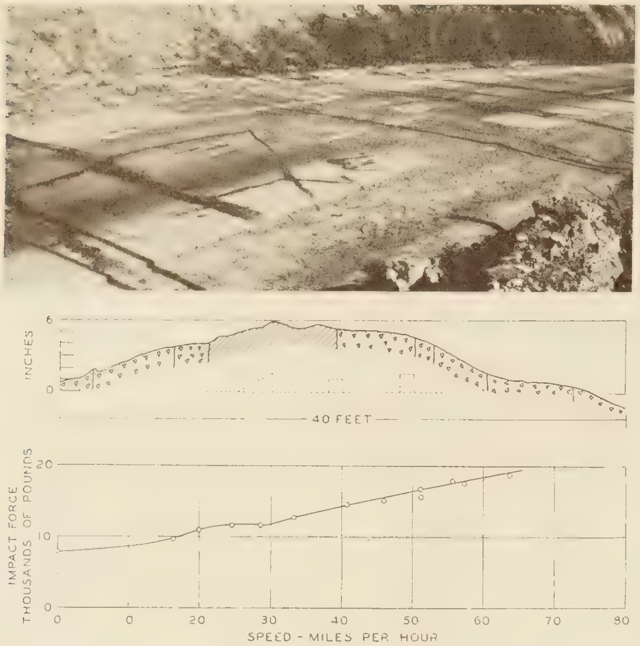


Figure 20.—Impact Reactions Produced on a Concrete Road at a Sharp Vertical Curve at the Top of a Hill

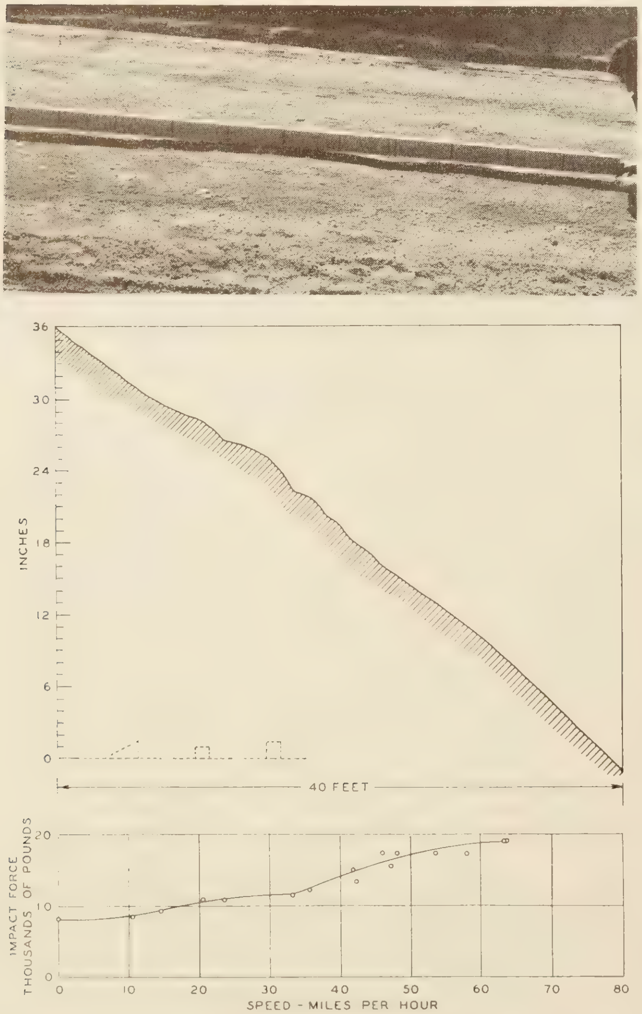


Figure 21.—Impact Reactions Produced on an Oiled Gravel Road by Corrugations on a Steep Grade

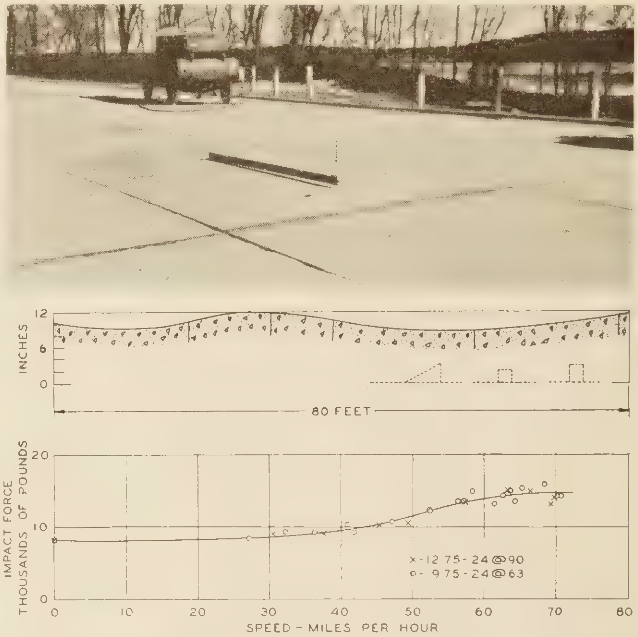


Figure 22.—Impact Reactions Caused by the Uneven Settlement of Fill Under a New Concrete Pavement. The Masonry Underpass of a Grade Separation Lies Directly Under the Hump in the Grade

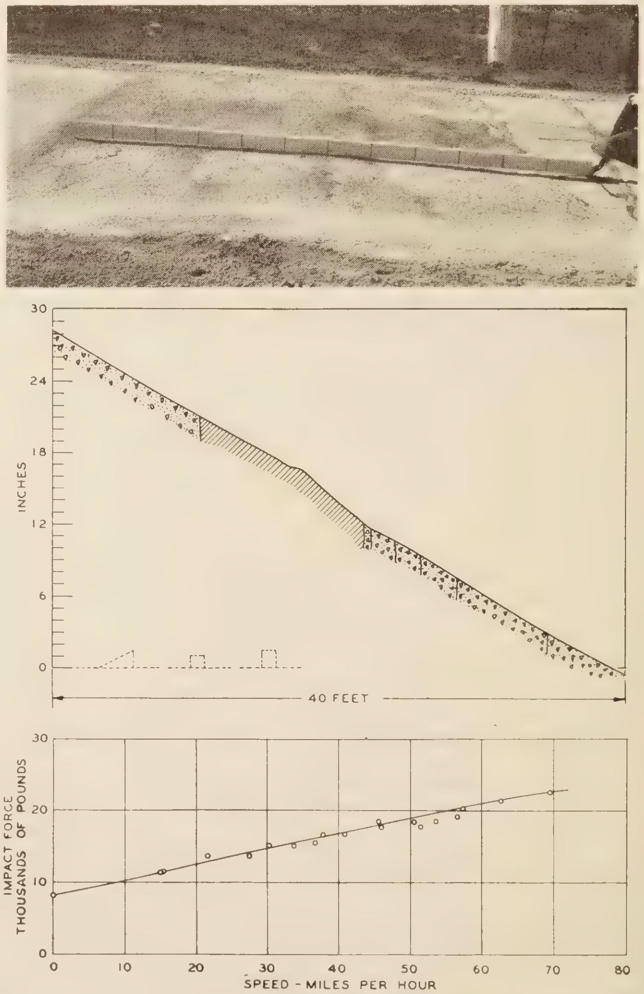


Figure 23.—Impact Reactions Produced on a Hill Where a Concrete Pavement Has Been Extensively Patched with Bituminous Mixture

ing the test the right rear wheel approached the obstruction along this smooth surface and at the instant of contact the body of the vehicle and the rear springs were in what may be termed the normal rolling position. Even during the impact at the right rear wheel, the other three wheels were passing over smooth pavement. Under such conditions the influence of the road surface adjacent to the artificial obstructions may be regarded as a minimum and probably negligible. In the case of the tests with the natural obstructions, however, such is not the case. The obstructions themselves conformed to no conventional design, the adjacent pavement was more or less uneven, the crown was not always flat nor the grade level. The profile of the road surface was even different under the two tires of the right rear wheel, an extreme case of this being shown in Figure 9. The result of these complicating factors was that the four wheels of the vehicle approached the natural obstruction over a surface that was not smooth and at the instant of contact of the right rear wheel with the rough place in the road surface the position of the vehicle body and the state of compression of the rear springs was being influenced by what had occurred and was occurring at all of the four wheels of the vehicle. It is, therefore, to be expected that the conditions attending the tests with the natural obstructions might combine to exert a considerable influence on the relation between the magnitude of the impact reaction and the speed of the vehicle.

Early in the tests involving natural obstructions it was indicated that the segregation and identification of shock and drop types of reaction would necessitate an undue length of time at each location. As the magnitude of the maximum reaction at a large number of rough spots was of greater significance, the force measured for each test run is the maximum developed, whether shock or drop in type. However, the shape of the force versus speed curves is, in many instances, characteristic of the drop type of reaction at the lower speed range and characteristic of the shock type at the higher speeds.

The data from the tests over the numerous natural obstructions evidence considerable variety in the shape of the curves showing impact force as influenced by vehicle speed. Because of the infinite variety of the roughness conditions which can and do occur on the highways, the results of tests involving only one rough spot or type of roughness condition should not be taken as representative of the reactions which may occur. So far as the tests involving these 28 natural obstructions may be considered to be representative, it is indicated that the maximum reactions developed by balloon tires on the highway are of the same order as the maximum reactions developed in the tests with artificial obstructions, or about three times the static wheel load. These tests also show that the maximum reaction on the road may occur at nearly any operating speed, depending upon the particular attributes of the surface roughness involved. As the roughness conditions on the road possess individual characteristics, each one unique with respect not only to the local roughness but to the general profile of the adjacent road surface as well, so do the relations between impact force and vehicle speed show corresponding individuality.

The conclusion, based upon results of tests with artificial obstructions on an otherwise smooth and level road, that the reactions may reach maximum values between 20 and 40 miles per hour, must be somewhat modified when the results of tests involving "natural" rough spots or obstructions are considered. In a few cases the reactions caused by the natural obstructions which were used do actually reach maximum values at a speed of 40 miles per hour or less. The preponderant tendency, however, is for the reactions to show a general increase with increases in speed.

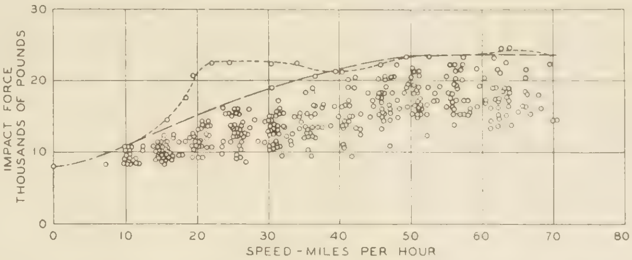


Figure 24.—Composite of All Data Derived from Tests Involving Severe Natural Obstructions

A better conception of the real significance of the reactions which may and do occur as a result of rough spots in the pavement surface may be obtained by referring to Figure 24, in which the data from all tests at the 28 locations have been plotted in a common graph. In this figure the dotted line represents the envelope of all the force versus speed curves for the individual conditions. The broken line, however, more nearly represents the maximum reactions to be expected throughout the speed range covered by this large group of data for natural roughness conditions. Between the limits of 15 and 30 miles per hour the dotted-line curve is based solely on points plotted from data which represent a single natural roughness condition. (See fig. 9.) The general trend, as indicated by the broken line, is for the reaction to increase up to a speed of about 50 miles per hour, when a general maximum is reached which is constant up to 70 miles per hour. The reactions, in percentage of static load, indicated by the broken line as maxima to be expected as a result of these natural obstruction tests, are given in Table 2.

Table 2.—*General maximum reactions produced by 28 natural rough spots on highways*

Speed	Impact reaction	Ratio of impact reaction to static load	Speed	Impact reaction	Ratio of impact reaction to static load
Miles per hour	*Pounds*	*Per cent*	*Miles per hour*	*Pounds*	*Per cent*
0	8, 000	100	40	21, 800	273
10	11, 000	138	50	23, 500	294
20	15, 200	190	60	23, 700	296
30	19, 000	238	70	23, 700	296

From this it may be concluded that the maximum reaction which a heavy vehicle equipped with balloon tires may be expected to produce when traveling over a large number of natural rough spots is about three times the magnitude of the static wheel load, and that at 40 miles per hour reactions of about two and three-quarters times the static wheel load or 92 per cent of the maximum may be expected to occur.

MAGNITUDE OF REACTION VERSUS FREQUENCY

The tests concerning the magnitude of impact reaction developed versus the frequency with which such forces occur on actual highways were made on 14 typical roads. Seven representative surface roughness conditions for each of the concrete and bituminous types of construction were selected in the same area in the vicinity of Washington in which the natural obstructions were found. The surface roughness of the seven roads in each group ranged from the best to the worst which could be found in the area examined. The length of each test section was one-half mile and none of the natural obstructions which were used in the tests previously described, or any other exceptional condition, was included in the representative test sections. Tests on each road were made at speeds of 20, 30, and 40 miles per hour.

These roads were selected in the following manner: Within the area surveyed a number of sections were considered to be of sufficient length and carrying such volume of traffic as to warrant consideration of them as representative surfaces. These sections were then examined with a device for indicating relative road surface roughness. This roughness indicator was described in PUBLIC ROADS, volume 7, No. 7, September, 1926. Although this instrument can not be said to measure the actual roughness of a road surface, it serves as a valuable guide in determining the relative roughness of road surfaces and it was so used in this investigation. Readings were taken at $\frac{1}{10}$-mile intervals over about 5 miles on each section, and from the data thus obtained a $\frac{1}{2}$-mile length was finally selected as uniform and representative of the section. It is interesting to note that the impact-frequency curves for the seven roads of each type arranged themselves, with one minor exception, in the same order as the road surfaces were classified with the relative roughness indicator.

The impact frequency tests were made at several speeds to avoid the arbitrary selection of any one speed in conducting the tests. The maximum speed was 40

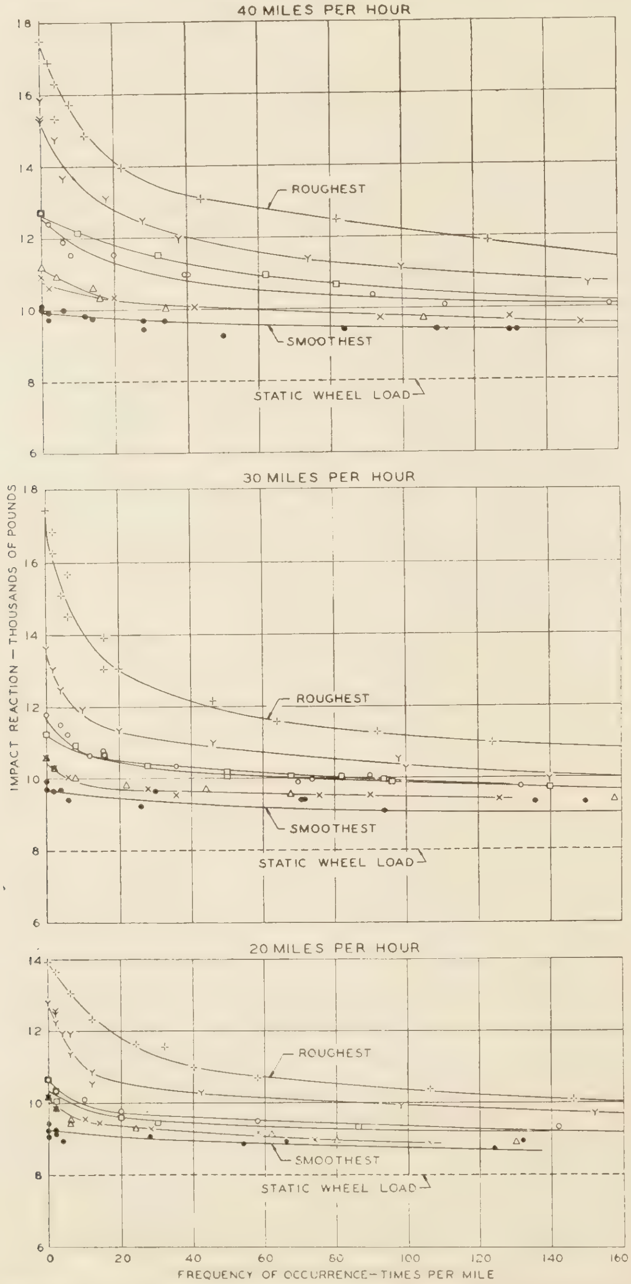


FIGURE 25.—CURVES OF MAGNITUDE OF IMPACT REACTION VERSUS FREQUENCY OF OCCURRENCE FOR CONCRETE ROAD SURFACES

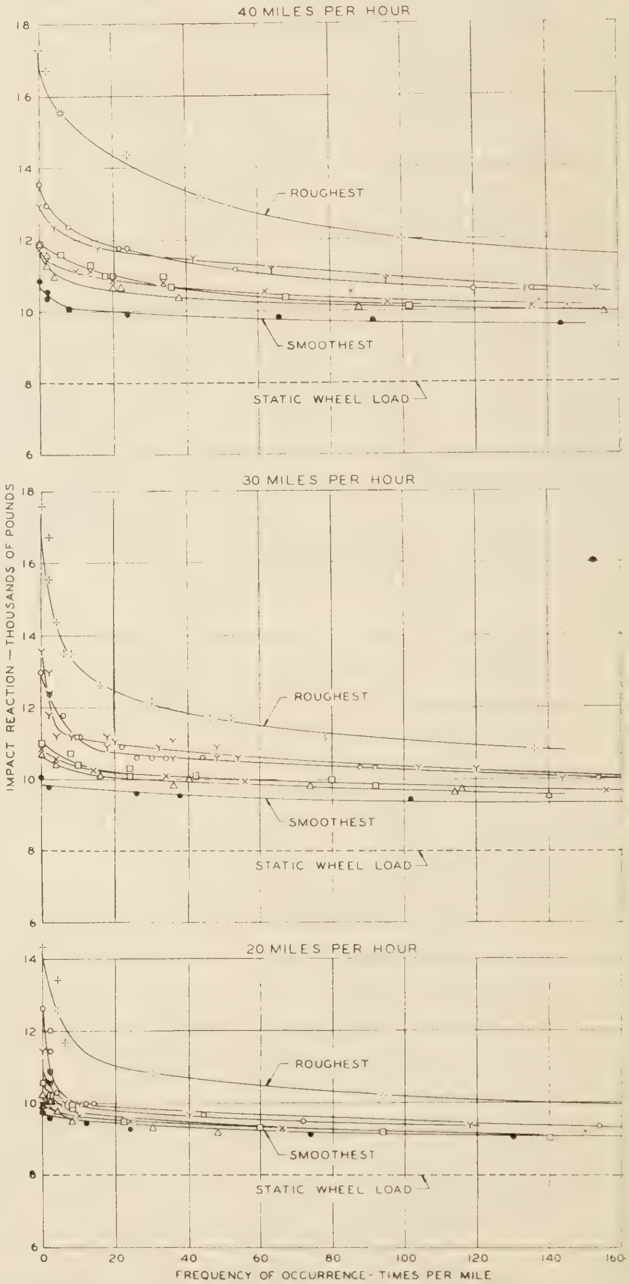


FIGURE 26.—CURVES OF MAGNITUDE OF IMPACT REACTION VERSUS FREQUENCY OF OCCURRENCE FOR BITUMINOUS ROAD SURFACES

Upper.—The Smoothest Concrete Surface Tested
Lower.—The Roughest Concrete Surface Tested

Upper.—The Smoothest Bituminous Surface Tested
Lower.—The Roughest Bituminous Surface Tested

Figure 27.—Examples of Roads on Which Impact-Frequency Tests Were Made

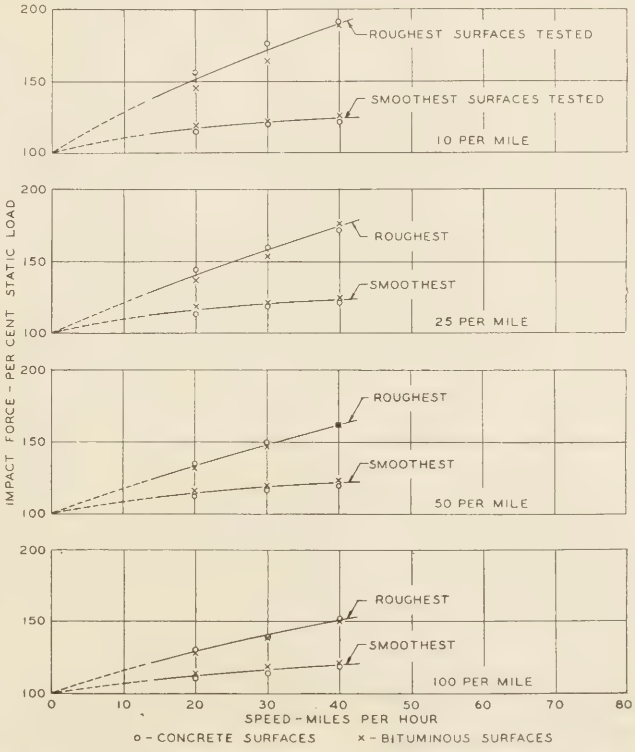


Figure 28.—The Influence of Road Surface Condition on the Impact Force-Frequency Relation

miles per hour, because that was the maximum which could be maintained conveniently on all of the half-mile test sections with safety and it was within legal speed limits. Higher speeds were not used because too much time would have been wasted in awaiting favorable traffic conditions to make the entire test run at constant speed without weaving in and out of traffic. In the previous tests involving artificial and natural obstructions it was found that maximum reactions were reached or reasonably approached at a speed of 40 miles per hour. Furthermore, tests conducted at this speed are representative of a considerable volume of normal traffic.

The force versus frequency data are presented in Figures 25 and 26. There is very little difference between the ranges of impact-producing roughness of the concrete and bituminous pavements tested. The smoothest surfaces and the roughest surfaces of each pavement type tested appear to be, respectively, of comparable orders. In Figure 27 photographs of the best and worst sections of each type are shown.

In Figure 28 the data are rearranged to give a more generalized picture of the range in forces produced as influenced by the frequency of occurrence and the vehicle speed. In this figure curves have been drawn representing the forces, expressed in terms of static wheel load, produced by the best and the worst surface conditions of the roads represented in the tests.

These force versus frequency data indicate that the effect of speed is of comparatively little significance when the road surface is reasonably smooth. Even on the smoothest surfaces reactions of from 110 to 125 per cent of the static wheel load occur with sufficient frequency to constitute a factor which should be considered in pavement design. As the surface roughness increases the frequency at which a given impact force

(Continued on p. 151)

EXTRA WIDE HIGHWAYS ON STATE SYSTEMS

THE accompanying table shows the extent to which the construction of State roads having more than two traffic lanes had progressed by the end of the calendar year 1931. A total of 3,790 miles was reported, of which 2,230 miles were of 3-lane width, 1,385 of 4-lane, 83 of 5-lane, and 92 of 6 lanes and over.

It should be noted these figures refer to rural highways on the State systems only. There is also a very great mileage of city streets and parkways having more than two lanes, including many broad traffic arteries which connect with the State systems at the city limits. No figures are available on the extent to which the counties have participated in the development of extra wide surfaces.

Wilkinson Boulevard, Between Gastonia and Charlotte, N. C.

The recently completed Mount Vernon Memorial Highway, 15 miles long, with a minimum width of 40 feet, is under the jurisdiction of the Federal Government, and is therefore not included in the mileage reported for Virginia.

The excess of 3-lane over 4-lane roads is very largely accounted for by the figures from the State of New York, which reports 914 miles of 3-lane road and only 185 miles having 4 lanes. Illinois, in contrast, has only 7 miles of 3-lane roads and 251 miles with 4 lanes.

The results of a cooperative study of highway traffic capacity were reported by A. N. Johnson, dean, College of Engineering, University of Maryland, in Public Roads, volume 13, No. 3, May, 1932. In this report it is stated that the working capacity of a 3-lane road, defined as the point at which congestion first becomes apparent, was found to be about 2,000 vehicles per hour, an increase of approximately 100 per cent over that of a 2-lane road. The working capacity of a 4-lane road was found to be about 3,000 vehicles per hour. Considerations of safety may influence the choice of a 4-lane width, as it eliminates the conflict between vehicles on the single passing lane, which may be an appreciable hazard with heavy traffic on a 3-lane road.

Only 175 miles of roads having more than four lanes have been built on the State highway systems. While such broad boulevards are not uncommon in large cities, there are few sections of State highways on which the traffic justifies the construction of more than four lanes. Even when there is sufficient volume, as in the case of a road connecting two great cities, the problem of distributing traffic at the urban terminals of a 6 or 8 lane highway is very difficult. It is very often preferable to open up an alternative route having four lanes or less.

40-Foot Brick Pavement North of Akron, Ohio

The dual road, in which the opposing traffic streams are separated by parkway or car tracks, has distinct advantages from the standpoint of safety, in addition to the opportunities for landscape treatment afforded by a central parkway. The increased width of right of way required and the cost of improving the separating strip are items which tend to retard the development of the dual road. Eighty-four miles of this type had been built at the end of 1931, of which 23 miles were built during that year.

Dual Highway Between Detroit and Ann Arbor, Mich.

Of the 3,790 miles of existing extra-wide highways, 1,008 miles were built in 1931. Of this total, 388 miles were of 3-lane, 600 of 4-lane, and 20 of greater than 4-lane width. It is apparent that the trend is toward 4-lane rather than 3-lane highways and that designs involving more than four lanes are not finding much favor at the present time.

MILEAGE OF EXTRA WIDE SURFACED ROADS ON STATE HIGHWAY SYSTEMS, 1931

[Includes only rural roads over two lanes wide, as reported by State authorities]

State	Total mileage of extra wide roads	Mileage classified by number of lanes				Mileage with contiguous lanes all of one type of surface																	Mileage with contiguous lanes of two types of surface											Dual roads—Lanes separated by parkway or trackway [2]		
						Total	Bituminous macadam and surface treatments [1]				Bituminous concrete				Portland cement concrete				Brick or other block pavement				Total	Bituminous macadam and cement concrete				Bituminous concrete and cement concrete				Brick or block and cement concrete				
							Number of lanes				Number of lanes				Number of lanes				Number of lanes					Number of lanes				Number of lanes				Number of lanes		Number of lanes		
		3	4	5	6 and over		3	4	5	6 and over	3	4	5	6 and over	3	4	5	6 and over	3	4	5	6 and over		3	4	5	6 and over	3	4	5	6 and over	3	4	4	6	8
Alabama	1.3		1.3			0.5										0.5																		[3] 0.8		
Arizona	None.																																			
Arkansas	3.7		3.7			.4										0.4							3.3		[4] 3.3											
California	314.3	184.6	77.2	13.0	[5] 39.5	226.4	[6] 36.8	[7] 26.9	5.9		20.8	3.8	5.4	[8] 6.2	66.5	32.5	1.0	[9] 20.6					87.9	4.8			[10] 1.0	55.7	14.0	0.7	[11] 11.7					
Colorado	1.9		1.9			1.9										1.9																				
Connecticut	39.6	1.7	36.0	1.9		39.2		2.5			1.5	2.0			0.2	30.9	1.9			0.2			.4		.4											
Delaware	24.7		24.7			3.7										3.2				.5			6.0						1.9				4.1	[12] 15.0		
Florida	38.2	37.0	.2	1.0		38.2	[13] 14.3		[13] 1.0		4.5				15.9				[14] 2.3	.2																
Georgia	28.8	17.2	11.6			24.1	2.6				1.2	6.8			10.1	3.4							4.7	[15] 3.3	[15] 1.4											
Idaho	None.																																			
Illinois	258.8	7.3	251.0	.5		258.8					.2				7.1	250.9	.5			.1																
Indiana	110.5	40.9	64.6	3.3	1.7	76.9	.2	1.4			3.1	.9	.3		11.2	48.6	.6	1.3	3.1	3.5	2.4	[16] 0.3	33.6	21.4	9.1			.8	[17] .3		[17] .1	1.1	.8			
Iowa	None.																																			
Kansas	None.																																			
Kentucky	None.																																			
Louisiana	13.4		13.4			13.4										13.4																				
Maine	36.8	36.8				34.3	.7								33.6								2.5	2.5												
Maryland	47.1	7.0	39.6		.5	14.1						3.8			.2	10.1							30.4		.7			6.8	22.9					[18] 2.1		[19] 0.5
Massachusetts	224.2	148.1	74.3		1.8	162.3	82.4	15.3			6.8	.7			30.2	25.5			[20] 1.4				36.0	27.3	8.0						[21] .7			[22] 24.8	[22] 1.1	
Michigan	205.9	6.7	172.8		26.4	176.8		.5			1.4	2.5			5.3	166.1		1.0					3.7						3.7							[23] 25.4
Minnesota	156.7	84.0	72.7			156.7					12.2	14.9			71.8	46.4				[24] 11.4																
Mississippi	.9		.9																															[25] .9		
Missouri	30.5		27.9		2.6	30.5										27.9		2.6																		
Montana	None.																																			
Nebraska	None.																																			
Nevada	2.9	2.0		.9		2.9	[26] 1.0		[26] .9						1.0																					
New Hampshire	9.5	9.5				9.5					3.7				5.8																					
New Jersey	332.5	236.9	82.7	3.7	9.2	327.7	17.3	11.9	1.5	4.6	218.1	59.4	2.2	3.6	.9	1.3			[20] .6	[20] 5.3		[20] 1.0												[27] 4.8		
New Mexico	None.																																			
New York	1,104.0	913.8	184.9		5.3	1,014.2									827.1	181.8		5.3					89.8	[28] 66.2				17.8	3.1			2.7				
North Carolina	45.3	31.3	14.0			45.3					25.3				6.0	14.0																				
North Dakota [29]	2.6	.8	1.8			2.6									.8	1.8																				
Ohio	176.7	101.8	23.7	51.2		173.0	14.9	.3	3.0		13.5	4.4	2.5		51.8	1.6	11.3		21.6	13.7	34.4		3.7						3.7							
Oklahoma	3.5	3.5				3.5									3.5																					
Oregon	None.																																			
Pennsylvania	82.5	59.9	17.1	3.0	2.5	57.1		.1		[13] 1.7	.8	.9			38.2	11.3	1.3	.8	1.5	.4	.1		25.4	19.4	4.4	1.6										
Rhode Island	58.3	3.7	54.6			58.3						15.1			3.7	39.5																				
South Carolina	16.2	7.9	6.3	1.5	.5	16.2					7.1	4.6	1.5	.3	.8	1.7		.2																		
South Dakota [30]	None.																																			
Tennessee	33.1	3.3	29.7	.1		32.7		4.9			.5				2.4	24.8	.1						.4					.4								
Texas	15.3	1.1	12.6		1.6	15.3						4.3			1.1	8.3						1.6														
Utah	4.7		4.7			1.4										1.4							3.3						3.3							
Vermont	None.																																			
Virginia	128.2	119.2	9.0			119.2	55.2				20.8				43.2																			[31] 9.0		
Washington	40.5	13.7	26.5		.3	35.8									9.3	26.5							4.7	4.4			.3									
West Virginia	20.1	10.1	6.7	3.3		18.4					.7		.8		6.3	1.3	1.2		3.1	3.7	1.3		1.7										1.7			
Wisconsin	176.5	140.2	36.3			176.5	[32] 116.2	[13] 11.6			.7				23.3	24.7																				
Wyoming	.6		.6			.6										.6																				
Subtotal		2,230.0	1,385.0	83.4	91.9		341.6	75.4	12.3	6.3	342.9	124.1	12.7	10.1	1,277.3	1,002.3	17.9	31.8	33.6	39.0	38.2	2.9		149.3	27.3	1.6	1.3	81.5	52.9	.7	12.5	3.8	6.6	57.4	1.1	25.9
Total	3,790.3					3,368.4	435.6				489.8				2,329.3				113.7				337.5	179.5				147.6				10.4		84.4		

---

[1] Bituminous macadam unless otherwise noted.

[2] These columns give mileage of roads with parkway, or railway track (not usable by motor vehicles) in center between more than 2 lanes of various types as noted.

[3] Car tracks on a 10-foot wide center strip, with 2 lanes of cement concrete on each side.

[4] Consists of treated gravel between concrete lanes.

[5] Includes 10.5 miles over 6 lanes wide.

[6] Includes 20.6 miles of treated gravel.

[7] Includes 24.0 miles of treated gravel.

[8] Includes 4.8 miles over 6 lanes wide.

[9] Includes 2.8 miles over 6 lanes wide.

[10] Includes 0.7 miles over 6 lanes wide.

[11] Includes 2.2 miles over 6 lanes wide.

[12] Consists of a 50-foot central grass parkway with 2 lanes of cement concrete on each side.

[13] Consists of treated water-bound macadam.

[14] Includes 1.8 miles of asphalt block.

[15] Consists of bituminous macadam and bituminous concrete.

[16] Over 6 lanes wide.

[17] Consists of bituminous concrete and brick.

[18] Consists of 2 lanes of bituminous macadam and 2 lanes of cement concrete separated by tracks.

[19] Consists of 4 lanes of bituminous macadam and 4 lanes of cement concrete separated by parkway.

[20] Consists of stone block pavement.

[21] 2 center lanes of bituminous concrete include tracks.

[22] Grass plot reservation in center, with lanes of cement concrete on each side.

[23] Consists of 4 lanes of cement concrete on each side of center parkway with tracks.

[24] Includes 7.8 miles of asphalt block.

[25] Consists of a 23-foot parkway in center and 2 lanes of cement concrete on each side.

[26] Consists of bituminous-treated gravel.

[27] Consists of 20 feet of bituminous concrete and 20 feet of cement concrete separated by a 20 foot gravel strip.

[28] Includes 2.2 miles of treated water-bound macadam and cement concrete.

[29] Excludes 69.3 miles of gravel roads 3 to 6 lanes wide reported as largely through cities and towns.

[30] Excludes 40.8 miles of 3 lane gravel roads reported as plain and treated.

[31] Consists of cement concrete lanes with railway tracks in central private way.

[32] Includes 103.8 miles of treated water-bound macadam.

STATE AND LOCAL GOVERNMENTAL AGENCIES EXEMPT FROM FEDERAL EXCISE TAXES

State and local highway officials who have the duty of purchasing gasoline, lubricating oil, automobiles, tires, or other articles and commodities on which excise duties were levied under the revenue act of 1932 may be interested in the following extracts from the regulations of the Bureau of Internal Revenue, United States Treasury Department.

From Regulations 42, relating to the taxes on telegraph, telephone, radio, cable facilities; transportation of oil by pipe line; safe deposit boxes, checks, etc.; and electrical energy—

> Art. 19. *Services rendered to the United States or to any State or Territory or to the District of Columbia.*—Telephone, telegraph, cable and radio dispatches, messages, and conversations relating to Government business, which originate in the United States and which are a charge against the United States, the District of Columbia, a State, or Territory, and are paid from the funds thereof, are exempt from the tax. Messages, conversations, and dispatches which are not paid from such funds are not exempt from tax, even though they relate to Government business.
>
> The words "State" and "Territory" include political subdivisions thereof, such as counties, cities, towns, and other municipalities.
>
> Art. 36 (in part). * * * The checks, drafts, or orders drawn by officers of the United States or of a State, county, or municipality, or of a foreign government, in their official capacities, against public funds standing to their official credit and in furtherance of duties imposed upon them by law are not subject to the tax.
>
> Art. 41 (in part). * * * Electrical energy furnished to the United States or to any State or Territory, or political subdivison thereof, or the District of Columbia is exempt from tax.
>
> This exemption does not apply to payments for electrical energy for domestic or commercial consumption furnished by governmentally or municipally owned electrical power companies.
>
> The exempt agencies must establish their right to exemption by submitting the necessary evidence to the person furnishing the electrical energy.

From Regulations 44, relating to the taxes on lubricating oil; brewer's wort and malt products; grape products; matches; soft drinks; and gasoline—

> Art. 9. *Exempt sales to States and political subdivisions thereof.*—If articles are sold directly to a State or political subdivision thereof for use in the exercise of an essential governmental function, the tax does not attach, but sales to a dealer or distributor are taxable even though the manufacturer has knowledge that the articles are destined for ultimate use by or resale to a State or political subdivision thereof. Sales to the Government of the United States, the District of Columbia, or a Territory or possession of the United States are taxable.

From Regulations 46, which deal with excise taxes imposed under Title IV of the revenue act of 1932 on sales by the manufacturer, producer, or importer, of tires and inner tubes, toilet preparations, furs, jewelry, etc., automobiles, motor cycles, etc., radio receiving sets and phonograph records, mechanical refrigerators, sporting goods, firearms, shells, and cartridges, cameras, candy, and chewing gum—

> Art. 17 (in part). * * * The tax does not attach to sales of any articles to States or political subdivisions thereof to be used in the exercise of an essential governmental function, provided such sales are made direct by the manufacturer to a State or political subdivision thereof without any intervening sale to a dealer or distributor.

The claim for exemption from these excise taxes is made by the manufacturer or producer, who must furnish the Bureau of Internal Revenue with satisfactory evidence that the purchase was made with Government funds and for the official use of the Government agency concerned.

Articles or commodities purchased under the tax exemptions outlined above must not be resold or appropriated to personal use, as such action is in violation of the Federal statutes and is punishable under section 1114 of the revenue act of 1926, which, as stated in Regulations 46, article 73, provides that—

> any person who willfully fails to pay or collect any tax due, file return or keep records, or who attempts in any manner to evade or defeat the tax, is subject to a fine of $10,000 or imprisonment, or both, with costs of prosecution, and is also liable to a penalty equal to the amount of the tax not collected or paid.

VITRIFIED BRICK ON CONNECTICUT AVENUE EXPERIMENTAL ROAD

Experiment No. 6, the most northerly portion of the Connecticut Avenue experimental road, was constructed of vitrified brick on a foundation of 1:3:7 gravel concrete. The photographs on the back cover of this issue show the method of construction and the appearance of the surface shortly after completion. The front cover shows the condition of the pavement in the summer of 1932 after 19 years of service.

The entire surface was constructed during the spring of 1913. On the concrete foundation a cushion of sand was spread, rolled with a 300-pound roller, and struck off to a true depth of 2 inches. The brick were laid in straight courses at right angles to the curb, and the surface was rolled with a 5-ton tandem roller until they were firmly bedded in the sand cushion. The joints were filled with two applications of 1:1 Portland cement grout, the first application being swept into the joints and the second squeegeed over the pavement. Immediately after completion of the grouting sand was spread over the pavement to a depth of one-half inch and kept wet for seven days. This procedure differed from modern methods in the thickness of the sand cushion and the use of cement rather than bituminous grout in the joints. In brick pavements to-day the sand cushion is seldom more than 1 inch thick.

Longitudinal joints were provided along each curb, but no transverse expansion joints were constructed and the ends of the pavement were practically fixed.

The experiment was constructed with brick obtained from many sources and of widely differing characteristics. They were laid in 14 subsections, A to N. The cost of the surface, including the concrete base, was $2.58 per square yard.

Sections K, L, M, and part of N were constructed over a heavy fill which some years ago settled to a considerable extent, causing failures in the overlying pavement and necessitating heavy repairs during 1919, 1920, and 1922. The fill has continued to settle and maintenance costs on these sections have been high. Such costs are not properly chargeable to surface maintenance and have not been included in the computations of maintenance charges.

A foundation failure occurred also at the junction of this experiment and the adjoining concrete pavement. This was apparently caused by expansion of the concrete, and the brick on a strip 2 feet wide are cracked and worn. The brick of section N are rough and badly broken.

There has been little or no transverse cracking, although a considerable number of fine longitudinal cracks have developed and in some cases extend through several sections. However, they seem not to have affected the behavior of the wearing surface. Except for the repair of defects directly caused by subgrade and foundation failure, maintenance on this experiment has been confined to the filling of these cracks with bituminous material. The cost of such maintenance to date has amounted to 20.10 cents per square yard.

The brick section remains in excellent condition, showing little wear and no indication of failure under a traffic of approximately 3,000 vehicles per day.

(Continued from p. 147)

occurs also increases and the influence of vehicle speed becomes of greater importance. On a moderately rough road a vehicle of the type used will develop reactions of the general order of 150 per cent of the static wheel load with a frequency of fifteen to twenty-five times per mile when traveling at the rate of 40 miles per hour. These data further indicate that twice the static wheel load may be taken as a general maximum value of the reactions which such a balloon-tired vehicle will produce with sufficient frequency to be considered in pavement design.

CONCLUSIONS

Considering as a whole these tests with a balloon-tire-equipped bus, it may be said that—

1. Reactions of about three times the static wheel load may be encountered in isolated cases, mostly where pavement failure has already occurred and repairs are necessary.
2. A few reactions amounting to twice the static wheel load may be expected for each mile of rough surface.
3. The frequent reactions for rough surfaces amount to about 1.5 times the static wheel load.
4. Even the smoothest roads produce frequent reactions of from 1.1 to 1.2 times the static wheel load.
5. Concerning the maximum reactions produced at a large number of individual roughness conditions, the general tendency is for this maximum to increase in approximate proportion to speed up to about 40 miles per hour, and at speeds greater than that comparatively slight increases in reaction are noted. However, occasional roughness conditions may occur where the maximum reaction developed at 20 or 30 miles per hour is as great as the maximum produced by the majority of the roughnesses at only the higher speeds.

WASHING MACHINE DESIGNED FOR USE IN DETERMINING CONSTITUENTS OF FRESH CONCRETE

By William A. Blanchette, Highway Engineer, U. S. Bureau of Public Roads

IN THE analysis of fresh concrete to determine the proportion of each ingredient contained in it the ingredients must be separated. One method is to wash the concrete on a No. 100 sieve, to reclaim the cement from the wash water, to split the aggregates into fine and coarse on the proper sieve and by the difference between the initial weight of the concrete and the weight of the sum of the solids reclaimed, to calculate the weight of the water. Another method, which is based on the Archimedes principle, and which is referred to as the Dunagan method, consists of weighing the concrete in air and in water, washing out all material passing the No. 100 sieve, determining the weight of cement by differences in immersed weights, converting immersed weights of cement, fine aggregate, and coarse aggregate to air weights, and determining the weight of water by differences in air weights.

Figure 1.—The Sample of Fresh Concrete to be Analyzed is Placed on the No. 4 Sieve Which is Directly Below the Perforated Pipe and Attached to Base Frame "A." Another Sieve is Placed on Cleats "B" Above the Pipe

Either method requires that the sample of concrete be washed on sieves, and in order to facilitate this washing process a washing machine was recently devised and used successfully in connection with the Dunagan method.

As may be seen in Figures 1 to 4, this machine consists of an octagonal drum mounted on a frame. No. 100 sieves are inserted in six places around the circumference of the drum, three in the top removable cover,

Figure 2.—Frame C is Placed over This No. 4 Sieve. This Frame Comes in Contact with the Top Cover and Holds the Sieve Firmly in Place. The Top Cover is Then Clamped in Postion and the Water Turned on

and three in the bottom cover, also removable. A perforated pipe to which the water line is coupled and through which the water is sprayed under pressure extends horizontally through the center of the drum. Two No. 4 sieves are inserted in the drum, one on either side of the water pipe. These form an inner compartment in which the sample to be washed is placed. The removable covers, containing the No. 100 sieve, are equipped with rubber gaskets and are clamped to the base frame so that all material leaving the drum must pass through the No. 100 sieve. Each piece of No. 100 sieve is reinforced on the outside with No. 4 sieve.

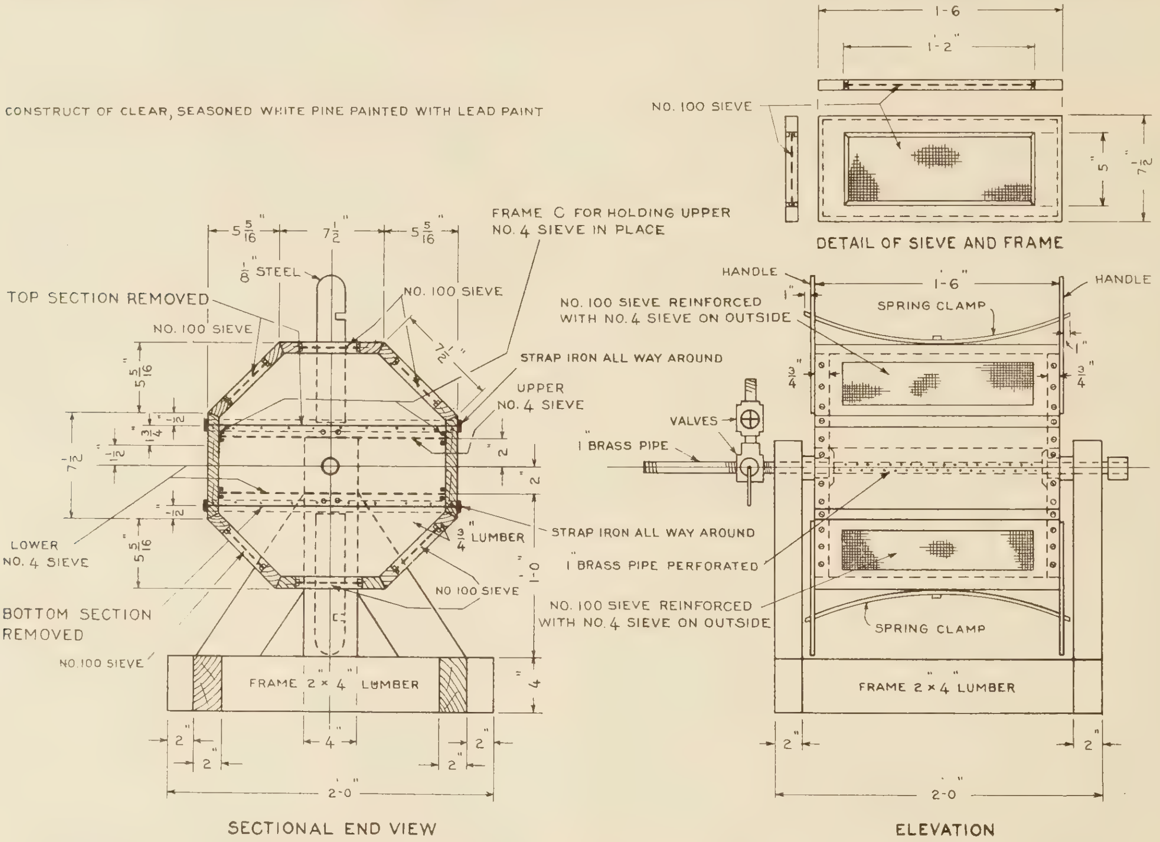


Figure 3.—Design of Washing Machine for Determining Constituents of Fresh Concrete

As may be observed in the photographs, the machine as actually constructed differs in certain details from the design shown in Figure 3. The handles attached to the covers are of wood, and the clamps with which the latter are affixed to the base frame are of a different type from those shown in the drawing.

The sample of fresh concrete is placed in the inner compartment on the lower No. 4 sieve which is attached to the base frame. The upper No. 4 sieve is then placed in position, and frame C, which holds this sieve firmly in place, inserted; thus confining the coarse aggregate so that it will not wear out the No. 100 sieve inserted in the top cover. The cover is then clamped in position, the water turned on, and the drum revolved and shaken until all material that will pass the No. 100 sieve has been washed out. By holding the drum so that the No. 4 sieves are in a horizontal plane and shaking the apparatus the fine aggregate is washed down through these sieves and is separated from the coarse aggregate. The fine aggregate is then removed in the bottom cover. After removing the upper No. 4 sieve and revolving the drum, with the top cover in place, the coarse aggregate is removed in the top cover. This machine is also used for determining the following correction factors (solids passing and retained on the 2-size sieves) which must be applied in the analysis: Fine aggregate passing the No. 100 sieve; fine aggregate retained on the No. 4 sieve; coarse aggregate passing the No. 100 sieve; coarse aggregate passing the No. 4 sieve and retained on the No. 100 sieve; cement retained on the No. 100 sieve; fine aggregate ground up during the mixing action so that it passes the No. 100 sieve.

Figure 4.—After All Materials Passing the No. 100 Sieve Have Been Washed out, the Coarse and Fine Aggregates are Separated and Removed from the Machine. The Fine Aggregate is being Removed from the Bottom Cover. The Coarse Aggregate is in the Top Cover

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

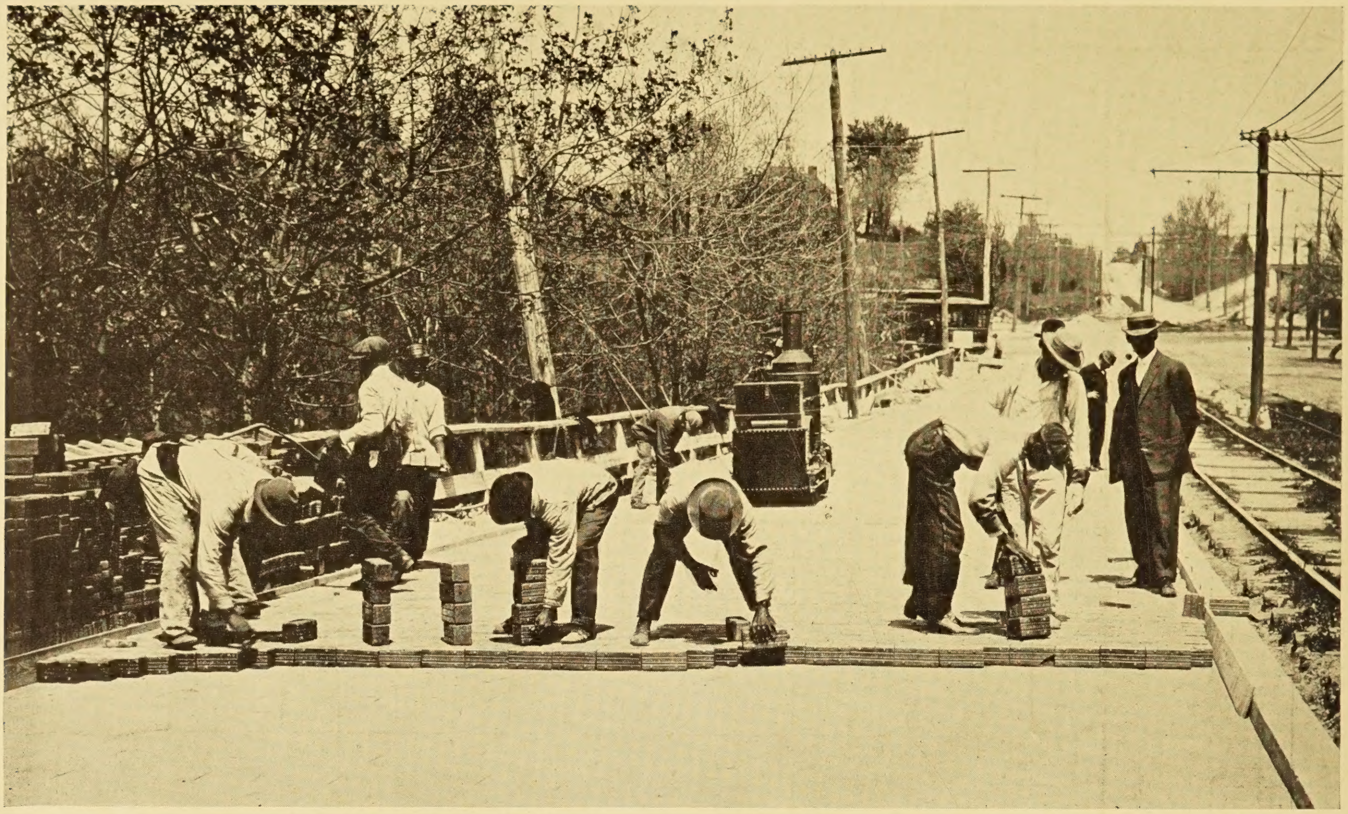
CURRENT STATUS OF FEDERAL-AID ROAD CONSTRUCTION

AS OF

OCTOBER 31, 1932

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION						APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal-aid allotted	Percentage completed	MILEAGE			Estimated total cost	Federal-aid allotted	MILEAGE				
					Initial	Stage[1]	Total			Initial	Stage[1]	Total		
Alabama	2,403.0	$ 2,700,450.56	$ 1,328,329.22	46	89.5	15.8	105.3	$ 975,959.82	$ 487,979.87	33.0	17.2	50.2	$ 4,261,827.01	Alabama
Arizona	1,215.5	3,251,725.93	1,699,161.37	66	114.5	117.8	232.3	209,427.52	41,885.51		32.0	32.0	247,631.71	Arizona
Arkansas	1,967.2	2,285,380.53	1,045,397.70	85	64.5	38.4	102.9	448,044.66	224,022.33	20.5		20.5	2,129,231.99	Arkansas
California	2,445.6	6,237,783.76	2,813,210.09	66	140.9	40.3	181.2	2,244,885.20	168,351.60	20.8	6.5	27.3	366,696.85	California
Colorado	1,671.8	2,987,153.64	1,542,919.32	87	110.1	62.7	172.8	133,878.96	60,245.51	9.6		9.6	1,678,307.24	Colorado
Connecticut	289.8	4,278,144.69	1,626,118.39	64	30.5		30.5	373,625.53	182,887.81	8.3		8.3	163,698.10	Connecticut
Delaware	371.5	748,723.35	334,281.00	94	18.6	2.0	20.6	269,495.80	53,200.00	10.2	9.2	19.4	88,740.82	Delaware
Florida	660.2	3,668,655.29	1,696,567.65	74	105.0		105.0	1,173,778.26	586,889.11	30.6		30.6	1,965,408.13	Florida
Georgia	3,183.6	5,745,668.03	2,502,053.46	63	118.3	147.1	265.4	1,565,830.33	553,012.17	80.0	38.5	118.5	83,106.02	Georgia
Idaho	1,298.7	3,211,402.96	1,743,857.80	90	140.6	294.2	434.8	928,590.90	218,637.19	47.3	36.0	83.3	214,700.11	Idaho
Illinois	2,874.8	23,724,195.58	10,184,987.71	83	730.0	40.6	770.6	2,937,914.13	616,883.16	97.8	4.7	102.5	513,891.73	Illinois
Indiana	1,883.2	10,328,537.06	5,131,611.19	90	387.5	15.9	403.4	48,197.89	24,098.94	4.7		4.7	343,412.82	Indiana
Iowa	3,330.4	7,782,312.82	2,461,967.61	90	371.8	81.7	453.5	977,998.29	18,423.25	38.6	1.2	39.8	9,652.78	Iowa
Kansas	3,734.6	2,852,716.39	1,288,978.89	67	165.5	143.6	309.1	2,551,455.41	543,473.56	177.8	19.2	197.0	365,781.58	Kansas
Kentucky	1,837.4	4,337,181.92	1,637,180.49	54	194.6	113.1	307.7	1,644,512.93	558,219.52	86.1	44.9	131.0	86,633.38	Kentucky
Louisiana	1,579.5	7,083,347.35	3,239,787.06	56	86.4	9.9	96.3	1,825,162.15	667,322.60	25.2	4.5	29.7	7,964.05	Louisiana
Maine	774.2	2,032,469.51	855,036.46	88	72.8		72.8	651,438.41	130,287.66	23.7		23.7	18,728.18	Maine
Maryland	805.8	1,419,044.25	672,714.42	76	56.6	4.7	61.3	528,288.35	41,220.75	17.7	1.5	19.2	20,768.90	Maryland
Massachusetts	831.9	7,301,674.93	2,573,484.99	79	79.3	5.0	84.3	550,120.53	80,000.00	10.0		10.0	15,743.13	Massachusetts
Michigan	2,224.1	7,811,835.19	3,428,567.50	75	320.5	51.2	371.7	1,069,561.73	390,977.50	67.2	17.7	84.9	790,188.17	Michigan
Minnesota	3,950.5	11,965,505.67	2,819,831.52	99	243.1	367.5	610.6	767,296.02	6,300.00	28.8	10.0	38.8	8,400.00	Minnesota
Mississippi	1,837.9	3,668,733.71	1,794,739.80	77	172.0	58.8	230.8	579,412.28	289,706.12	29.7		29.7	4,627,266.31	Mississippi
Missouri	3,106.5	3,694,249.88	1,358,220.34	76	82.3	44.6	126.9	1,548,969.71	302,219.71	93.3	2.9	96.2	310,455.24	Missouri
Montana	2,685.9	5,189,717.36	2,872,969.39	69	394.2	206.2	600.4	1,801,284.29	1,013,270.73	183.4	27.6	211.0	1,122,184.01	Montana
Nebraska	4,216.8	4,026,592.31	1,949,067.39	65	112.2	131.9	244.1	1,337,109.29	614,815.84	48.3	36.9	85.2	1,150,560.55	Nebraska
Nevada	1,334.9	1,792,520.82	1,426,209.59	80	38.4	118.9	157.3	501,415.15	66,134.78		44.0	44.0	63,225.46	Nevada
New Hampshire	424.8	752,333.19	341,340.93	69	24.8	3.4	28.2	46,112.96	18,445.18	1.2		1.2	248,048.21	New Hampshire
New Jersey	623.6	7,499,000.63	2,625,546.51	51	65.6	.5	66.1	359,376.90	124,468.87	3.8		3.8		New Jersey
New Mexico	2,245.3	1,869,960.82	941,895.83	54	92.8	56.7	149.5	698,696.99	294,099.83	48.2	42.1	90.3	590,422.98	New Mexico
New York	3,336.5	21,648,110.00	7,498,610.00	56	554.6	29.1	583.7	2,440,100.00	730,360.00	58.1	2.3	60.4	820,773.72	New York
North Carolina	2,248.1	1,478,974.04	734,458.25	57	126.0	9.0	135.0	1,836,407.57	924,917.66	258.7	17.3	276.0	2,604,253.12	North Carolina
North Dakota	5,018.0	4,523,809.23	1,788,721.71	67	464.3	528.3	992.6	1,397,931.61	753,414.66	53.6	288.4	342.0	116,523.08	North Dakota
Ohio	2,880.7	10,145,962.64	3,400,297.84	76	253.3	93.0	346.3	1,823,290.00	328,306.67	34.4	5.5	39.9	669,570.13	Ohio
Oklahoma	2,360.9	3,834,682.08	1,871,212.42	84	184.0	43.5	227.5	1,792,617.59	715,468.62	88.1	19.9	108.0	726,934.11	Oklahoma
Oregon	1,624.9	2,506,123.62	1,232,197.16	65	60.1	62.1	122.2	683,698.40	210,887.60	13.6	40.0	53.6	626,368.86	Oregon
Pennsylvania	3,089.4	9,027,731.37	3,670,388.20	66	346.5		346.5	2,693,201.15	483,604.73	77.1	5.8	82.9	819,667.01	Pennsylvania
Rhode Island	263.8	1,080,305.71	317,616.79	53	19.1	4.3	23.4	188,252.22	94,126.10	.1		.1	92,133.54	Rhode Island
South Carolina	2,001.7	2,919,748.47	1,162,992.73	52	153.1	101.1	254.2						293,595.40	South Carolina
South Dakota	4,002.6	4,752,491.41	2,194,763.65	65	384.8	299.8	684.6	128,424.30	69,435.71	26.0	.5	26.5	84,325.73	South Dakota
Tennessee	1,691.3	3,440,213.76	1,717,324.83	23	111.7	34.4	146.1	1,446,968.91	723,484.40	59.0	14.7	73.7	1,226,242.70	Tennessee
Texas	7,796.5	15,057,146.88	6,612,360.45	63	712.4	383.0	1,095.4	5,264,974.51	1,613,274.20	231.8	190.4	422.2	1,239,807.76	Texas
Utah	1,147.5	1,483,070.52	995,109.39	84	98.6	124.4	223.0	965,284.08	260,768.75	40.3	15.4	55.7	325,780.84	Utah
Vermont	358.5	849,927.15	347,113.53	89	37.7	.	37.7	120,039.42	10,803.56	5.4		5.4	36,721.46	Vermont
Virginia	1,918.4	3,142,504.00	1,536,142.11	64	181.5	19.3	200.8	1,643,169.56	652,111.70	73.7	15.8	89.5	823,471.32	Virginia
Washington	1,243.3	2,718,102.75	1,226,820.63	95	97.4	7.4	104.8	1,630,534.58	480,291.47	67.5	1.1	68.6	331,188.24	Washington
West Virginia	913.1	2,050,270.79	811,407.38	75	59.0	5.0	64.0	1,647,906.40	608,787.09	64.1	8.1	72.2	232,290.56	West Virginia
Wisconsin	2,589.6	9,492,129.96	3,178,900.49	86	275.2	128.0	403.2	415,831.21	82,670.62	9.6	17.8	27.4	59,329.44	Wisconsin
Wyoming	1,992.5	3,115,757.93	1,830,037.87	83	173.3	212.3	385.6	650,775.16	17,710.82	79.9	30.2	110.1	6,921.26	Wyoming
Hawaii	74.8	1,801,111.47	1,089,806.49	36	50.5	1.7	52.2	540,398.15	240,210.28	11.5	1.9	13.4	964,574.81	Hawaii
TOTALS	102,361.1	255,315,191.91	107,152,315.54	71	8,966.0	4,258.2	13,224.2	56,057,645.21	17,378,113.74	2,498.3	1,071.7	3,570.0	33,593,148.55	TOTALS
Construction completed		170,634,000.00	76,555,000.00											
Balance uncompleted		84,681,000.00	30,597,000.00											

[1] The term stage construction refers to additional work done on projects previously improved with Federal-aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.



LAYING PAVING BRICK ON THE CONNECTICUT AVENUE EXPERIMENTAL ROAD, APRIL, 1913

CONDITION OF BRICK SURFACE IN JUNE, 1913

U. S. GOVERNMENT PRINTING OFFICE: 1932